Scientific Programming

Scientific Programming for Smart Internet of Things

Lead Guest Editor: Mian Ahmad Jan

Guest Editors: Houbing Song, Muhammad Usman, and Rahim Khan

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Retraction

Retracted: Research on Distance Teaching System of English Course Based on Wireless Network Technology

Scientific Programming

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] S. Zheng, "Research on Distance Teaching System of English Course Based on Wireless Network Technology," *Scientific Programming*, vol. 2021, Article ID 3275340, 12 pages, 2021.

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Retraction

Retracted: Design of Ideological and Political Multimedia Network Teaching Resources Integration System Based on Wireless Network

Scientific Programming

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[1] L. Rong, "Design of Ideological and Political Multimedia Network Teaching Resources Integration System Based on Wireless Network," *Scientific Programming*, vol. 2021, Article ID 4293771, 15 pages, 2021.

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Retraction

Retracted: A College Music Teaching System Designed Based on Android Platform

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The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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Retraction

Retracted: Research on Analysis and Classification of Vulnerability of Electromagnetic Pulse with a STM32 Single-Chip Microcomputer

Scientific Programming

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Scientific Programming has retracted the article titled "Research on Analysis and Classification of Vulnerability of Electromagnetic Pulse with a STM32 Single-Chip Microcomputer" [1], due to concerns with the authenticity of the data. It was found that previous versions of this submission contained a figure unrelated to the topic of the paper and this graph was subsequently identified within several other submissions, all with accompanying text claiming to have generated the graph. A number of these submissions were rejected from the journal; however, 6 were published and have now been retracted from *Security and Communication Networks* and *Scientific Programming* [2–6].

The authors responded to explain that an author from one of the identified submissions had provided copy editing for their manuscript and introduced the graph and accompanying text in error.

The authors were unable to provide copies of correspondence to support their claim or the raw data from their study. The authors' explanation did not satisfy the concerns of the editorial board, and the article is therefore being retracted due to concerns with the reliability of the data.

The authors do not agree to the retraction.

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Hindawi
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Research Article

The Use of Stemming in the Arabic Text and Its Impact on the Accuracy of Classification

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The ongoing growth in the vast amount of digital documents and other data in the Arabic language available online has increased the need for classification methods that can deal with the complex nature of such data. The classification of Arabic plays a large and important role in many modern applications and interferes with other sciences, which start from search engines and do not end with the Internet of Things. However, addressing the Arab classification errors with high performance is largely insufficient to deal with the huge quantities to reveal the classification of Arab documents; while some work was tackled out on the classification of the Arabic text, most of the research has focused on English text. The methods proposed for English are not suitable for Arabic as the morphology of the two languages differs substantially. Moreover, morphologically, the preprocessing of Arabic text is a particularly challenging task. In this study, three commonly used classification algorithms, namely, the K-nearest neighbor, Naïve Bayes, and decision tree, were implemented for Arabic text in order to assess their effectiveness with and without the use of a light stemmer in the preprocessing phase. In the experiment, a dataset from Agency France Persse (AFP) Arabic Newswire 2001 consisting of four categories and 800 files was classified using the three classifiers. The result showed that the decision tree with light stemmer had the best accuracy rate for classification algorithm with 93%.

1. Introduction

Machine learning (ML) is a branch of Artificial Intelligence (AI) research [1], which aims to develop practically relevant multipurpose algorithms based on a little amount of data. Difference between ML approaches and general AI lies on the discovered patterns in data and the way in which data is used. There are different examples of the application of ML, such as fraud discovery, weather forecasting, and patients' diagnosis. The two major forms of ML are supervised and unsupervised learning. Here we consider the former, which involves the generation of a mapping from labeled training data into an output of predictions or classes. This process can be described as classification and is the core aspect of supervised ML.

Classification involves the determination of output values known as classes or labels using input objects. This mapping is known as a model or classifier. The entered objects are related to the categorized objects also recognized as examples, instances, or tuples. According to [2], ML classification technique involves combining several instances together with their known labels by manually tagging a group of instances. The group of labeled instances is recognized as a training set. The labeled instances (i.e., training set) are used by classifier to generate the model that maps the instance to its label. As a result, then the training model can be used to label or classify new, unknown instances. In the current study, which focuses on the classification of Arabic text, the instances are carefully chosen from a prelabeled pool of instances by employing enhanced Arabic classifiers.

There are many situations in which unlabeled documents are both plentiful and cheap. However, labeling them is regarded as costly and time-consuming. For example, it is handy to get a huge amount of documents basically with no price; in contrast a lot of money is paid for human comment hosts to classify these documents with their subject classification whether they are in Arabic or non-Arabic. Also, data for videos is easy to collect, but it is very difficult to get good semantic content labels from that data. Likewise, it is easy to get a wide range of compounds that may be useful for treating a disease, but it is very expensive to run expensive biochemical tests to see which one really works. These three examples are essentially classification problems.

Several algorithms have been implemented to solve the text classification (TC) problem. More than one work in this field has focused on English text. In contrast, little research has been done on the Arabic script. The English text differs from the Arabic text in terms of its morphological structure, which makes the preprocessing of Arabic text more challenging for a number of reasons. The aim of the study is to evaluate the performance of the Arabic text classification system using three distinct categorization methods, namely, the decision tree (DT), Naïve Bayes (parametric-based), and K-nearest neighbor (KNN) (example-based) classifiers. In order to get the best integration of weighting scheme and technique, various weighting schemes were adopted in the first two methods.

In the following, Section 2 discusses text classification. Then we present the motivation and objective of this work in Section 3. An overview of the related works and the three classifiers considered in this study are provided in Section 4. Section 5 introduces the framework of the proposed Arabic text classifier. Section 6 describes the experiment and Section 7 presents the document representation. Section 8 presents results and Section 9 contains the conclusion and details of future work.

2. Text Classification

Text classification is a machine learning supervised task requiring prelabeled documents in need of learning. Furthermore, it aims to detect new documents based on certain learned criteria [3]. Applications of text-based knowledge and the TC feature are particularly important in natural language processing (NLP), at least because of the recent increase in the volume of available text data. One example of an area in which TC and NLP are needed is filtering [4], which is a process that attempts to filter a user's inbound documents to identify those that are unwanted or unsolicited. Another is sentiment analysis [5], which looks to identify the general feelings cleared up in a document in order to measure, for example, customer satisfaction.

It is possible to apply the supervised learning algorithms of the classification training model to a set of respective problem states to overcome the problems encountered in the TC. These models can then be used to identify the unlabeled document class [2, 6–10].

There are two phases in the TC approach: training and testing. The training phase involves the building of a classifier using a group of the collected documents (called the training set) and by allocating a subset of the training set to each category before processing them via several NLP techniques. The aim of this processing is to extract the set of features from the training set which will be used as the representative for each category. The remainder of the collected documents is the so-called test set, which is used in the testing stage to evaluate the performance of the classifier in terms of its ability to classify the documents that it has not seen before into the correct categories, where performance is assessed by comparing the categories selected by the classifier with those of the predefined documents [3].

A TC system generally consists of these parts:

(i) Text preprocessing, which converts the text into a group of dimensions that can be processed by classifiers.

(ii) Reducing dimensionality, which decreases features number to enhance the efficiency of classification algorithms. This can be done using methods such as feature selection and dimension reduction [8, 9, 11, 12].

(iii) Classifier training, which is the process of building an autonomous classifier using supervised learning frameworks [2].

(iv) Prediction, which is the process of using a trained classifier to generate labels for new documents [2].

It has been indicated in [13] that texts can be symbolically represented as a set of characteristics by employing two representation methods, namely, the n-gram and the bag of words (BOW). The former involves the use of some words or sentences as characteristics while the latter employs the order of the words or characters of *n* length. Past studies [14, 15] have pointed out that the creation of an accurate TC system requires the effective handling of a high number of characteristics or features (which may be number in their tens of thousands). Hence some information retrieval (IR) techniques such as stemming and elimination of stop-words have been used to decrease the feature space dimensionality.

3. Motivation and Objectives

The importance of using technologies for classification has increased due to the need to have the ability to automatically classify the huge amounts of diverse text-based information that can be found on the Internet and in electronic/digital format in many languages, including Arabic. Hence, several studies initially focused on addressing the challenges associated with standard Arabic document classifiers [6, 7, 9, 16], which then encouraged more studies that concentrated on enhancing the performance of Arabic document classifiers. This research continues because most Arab classifiers are characterized by their inability to deal accurately with the vast quantities of documents that have been identified as Arabic documents. As such, this is considered the major problem in the classification of Arabic texts.

One of the main obstacles facing researchers working in the field of text classification for documents in Arabic is the failure of the available classifiers to deal with stemming, which is a factor that might affect other processes in a document classification system. To address this issue, an algorithm is employed to define the stemming rule, and this rule depends on the processing of grammatical components of an utterance to solve the complexity of morphological and syntax.

The major TC problem is related with the enormous features extracted from the text (can reach hundreds or thousands). Therefore, the time required to substitute a term with its possible concepts may increase and the high dimensionality of the feature space may reduce classifier performance. The number of features or feature size can be reduced by extracting the essential semantics from texts [17, 18].

Therefore, in order to reduce the feature size of Arabic text, this study evaluates three classifiers without and with stemming [19]. It is hoped that the outcome of this research will contribute to the improved tracking and detection of new documents and their categorization into the relevant categories and consequently, the improved performance of Arabic classifiers. In sum, this study attempts to answer the following research question: What is the effect of classification techniques on Arabic documents without or with the use of stemmer?

4. Related Works

Text classification refers to assigning predefined categories of text depending on the content of the documents. For natural language processing and other applications of textual knowledge, text classification is important. The importance of text classification is due to the recent increase in the volume of available text data. It is possible to overcome the problems of text classification by applying supervised learning algorithms to train the models of classification with a group of abovementioned examples of the problem in question that clarify correct classification (labels). These models can then be used to predict the labels of unlabeled documents [12, 20–23]. A text classification system may be built from the following components.

It is supposed that the structure of categories is known in advance in the case of supervised algorithms, and these algorithms require a group of tagged documents to map the documents to some prespecified classes. However, as abovementioned, in case of huge dataset it is difficult to remark the true label and class of the document in training set. Hence, the focus and review in this section will be on the most commonly used classification based on algorithms, namely, KNN, NB, and DT.

4.1. K-Nearest Neighbor Algorithm (KNN) Classifier. KNN is a popular example-based classifier. There are two basic steps, the KNN was developed as a popular instance-based learning technique which has been efficient in several text categorization tasks. The flow of the algorithm is boiled down as follows: first, the k-nearest neighbors are found within the given training documents [24]. Second, the test document category is found using the category labels of these neighbors. The conventional approach usually assigns the test document with the commonest label of category among the established k-nearest neighbors.

The conventional KNN is the basis of the extended weighted kNN in which the contribution of each neighbor is weighted with respect to its proximity to the test document. Next, the similarity of the adjacent documents in each class is collected to obtain the document class score; i.e., the class score cj for x document is illustrated as follows:

$$Score\ (cj, x) = \sum (di \in N(x)) \cos(x, di). y(di, cj), \tag{1}$$

where the training document is $= di$, group of x nearest k training document is $= N(x)$, cos $(x, di) =$ the cosine similarity between x and d_i, and $y\ (di, cj) = a$ function with a value of 1 if d_i is relevant to class cj, and 0 else. The class with the highest score allocates x test document.

4.2. Naïve Bayes (NB) Classifier. The NB classifier is a simple probabilistic-based classifier, which is based on Bayes' theorem which estimates the likelihood of the classes assigned to a test document using the joint probabilities of terms and classes of such document. The naïve aspect of the classifier originated from its assumption of the conditional independence of all terms of each category from the other category. Based on this assumption of independence, the parameters of each term can be separately learned, as such, making the computation operations easier compared to the non-NB classifiers. An NB proper classifier can merely assume that there is no relation between the presence or the nonappearance of a particular category trait with any other feature. We can express this presumption as follows:

$$P(C\_i|d) = \frac{(P(C\_i)P(d|C\_i))}{(P(d))}, \tag{2}$$

where $P(C_i\,|d)$ refers to the previous probability of class C_i in the presence of a new instance d and $P(C_i)$ symbolizes toe probability of class C_i, which can be figured by

$$P(\mathrm{Ci}) = \frac{\mathrm{Ni}}{\mathrm{N}}, \tag{3}$$

where the proper samples that are associated with class $C_i = N_i$, N is the number of classes, the likelihood of a sample d being assigned to a class $C_i = P(d|C_i)$, and the likelihood of sample $d = P(\mathrm{d})$.

4.3. Decision Tree (DT) Classifier. The DT is a commonly used inductive learning method that is characterized by its ability to resist noisy data and its ability to learn detailed expressions, which makes it suitable for document classification [25]. This algorithm employs a "divide and conquer" approach, where it divides complex decisions into several simpler ones.

It divides complex decisions into several simpler ones. In the learning stage of the DT, it is contained from a group of tagged training examples manifested in a record of features values and a label class due to big areas of decision tree learning and search are top-down, repeated process and greedy start with an empty tree and the entire training data. A feature has more information about content and has a best partition chosen as the splitting feature for the training data and for the root and then the training data is divided into disjoint subgroups satisfying the values of the incision features. In respect of every subgroup, the algorithm occurs before repeatedly until each subgroup's classes maintain the same class [3].

5. Framework of Arabic Text Classifier

When answering the user's demand, the TC system requests to get the following: classify the intended document, classify it swiftly, meet user requirements, and obtain optimum classification efficacy [26, 27]. Thus, the objective of the Arabic TC (ATC) structure presented in this study is to raise the ATC system efficiency, if the system takes into account the semantic relationship and the complexity of the Arabic terms.

The ATC framework depends on the following stages: preprocessing, extraction, representation, application of classifiers, and evaluation. The ATC framework takes into account these important issues (Figure 1).

The ATC system's first step is the preprocessing phase, which is an important step for document presentation. It involves the initial processing of the text to choose the appropriate terms to be indexed. Through the preprocessing phase, many operations are performed like stemming, stop-words eliminations, tokenization, and normalization.

In this study, the main contribution is to build an automatically Arabic text classifier to classify documents based on morphological knowledge representation by utilizing a light stemmer. The general procedures performed in this method are as follows (Figure 2).

Figure 3 shows the different stages of the ATC framework which will be discussed in detail in Section 6, "Experiment."

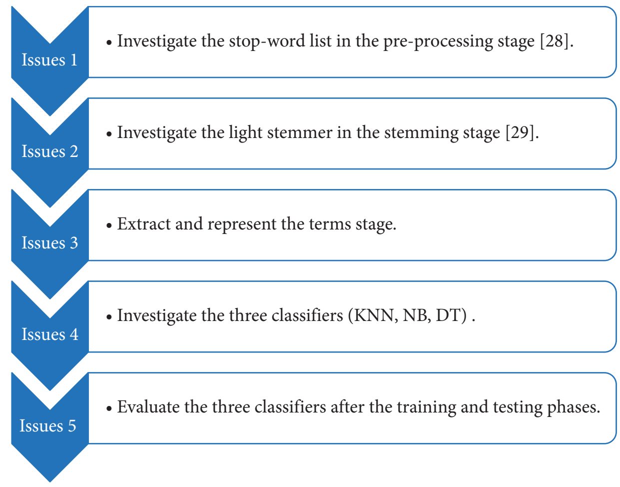

FIGURE 1: Important issues.

6. Experiment

Arabic-language classification is a supervised learning-dependent process; three ML processes and supervised algorithms were used in this experiment, the KNN, NB, and DT classifiers [28]. In order to enhance the accuracy of the Arabic classifier, the Arabic Light10 stemmer was employed and tested. In this section, the steps shown earlier in the Arabic text classifier framework were presented and tested.

6.1. Dataset. We used a dataset that consisted of 800 documents that were classified into four classes. These documents were extracted from the relevant documents for four queries (i.e., each query represents class) from an Arabic Newswire dataset that were used recently in TREC experiments [29]. Figure 4 shows a sample document from the dataset.

6.2. Preprocessing. The aim of the preprocessing phase is to filter out nonsignificant data, such as tags (i.e., <DOC>, <DOCNO >, <DOCTYPE>, <DATE_TIME>, <BODY>, <TEXT>, <END_TIME>) from a document. In carrying out the step of preprocessing, the document must be converted into a format suitable for the representation process so that learning algorithms are applied. Following this, removal of the unnecessary words used as the characters such as punctuation and special markers takes place. Thus, in carrying out this step, three commonly identified tasks, tokenization and normalization, stop-word removal (in order to reduce the dimension of the feature space), and mainly stemming and lemmatization, need to be done. Based on the review of these tasks in previous studies, the following section provides a brief description of these three tasks.

6.3. Tokenization and Normalization of Data. According to [31], text documents are usually converted in a way that is appropriate for their analysis by employing a machine learning algorithm. The text is divided into separate units by using either spaces or special symbols. As such, every word in a text is represented as a single unit. This procedure is called tokenization. For instance, (خير جليس في الزمان كتاب) it can be tokenized using white space to list of tokens (words) as (خير، جليس، في، الزمان، كتاب). Accordingly, the other task known as normalization is useful because this is done before the task stemming particularly for the Arabic script. This is for the reason that the text normalization in the Arabic language helps in the downgrading the various shapes of characters to produce a uniformed shape representing these shapes. This is illustrated by the following example:

(i) Substitute آ, إ as well as أ by ا

(ii) Substitute the last ة by ه

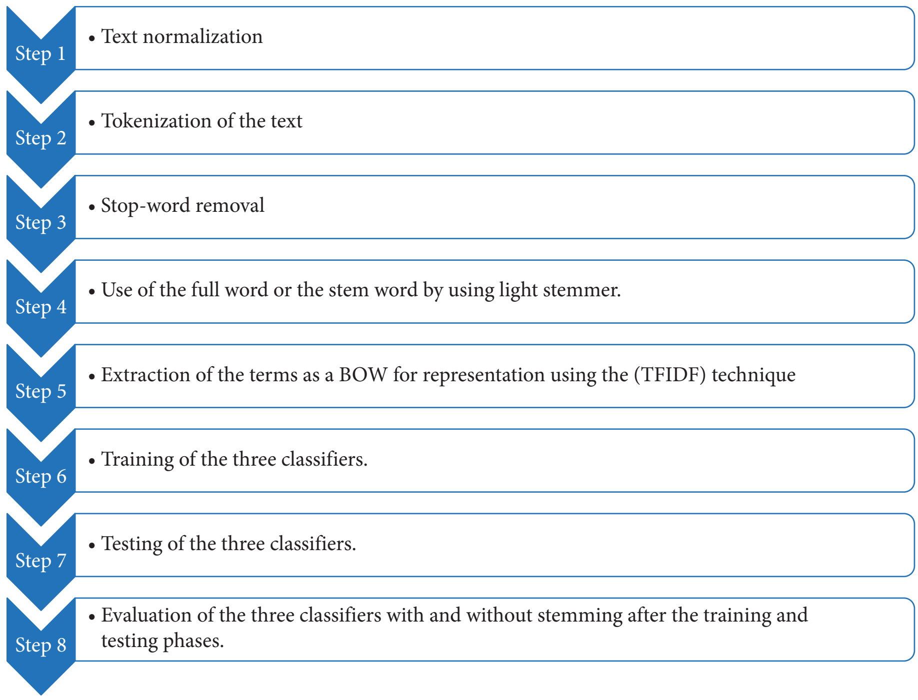

Figure 2: General procedures performed in this method.

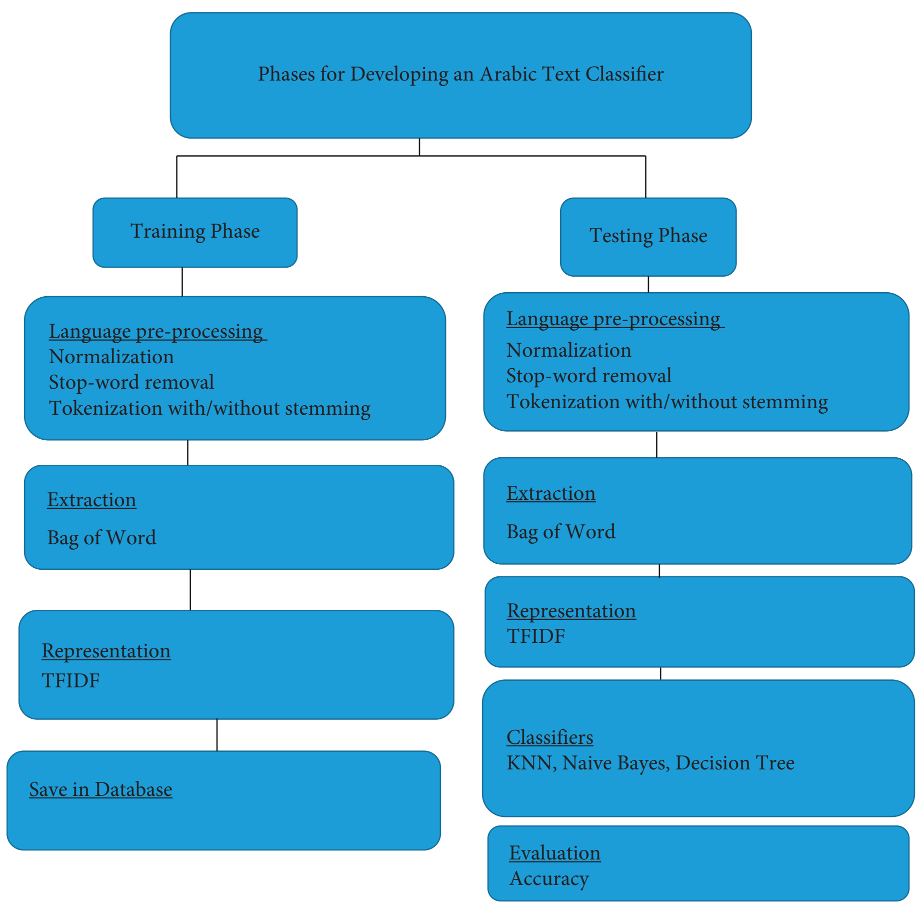

Figure 3: Phases for developing an Arabic classifier.

```
<DOC>
<DOCNO>19940513_AFP_ARB.0004</DOCNO>
<HEADLINE>
&HT;   واشنطن بوست: اسلحة ايرانية للمسلمين والكروات
</HEADLINE>
<TEXT>
واشنطن 31-5 (اف ب) - افادت صحيفة واشنطن بوست اليوم الجمعة ان ايران سلمت مطلع ايار/مايو ستين طنا من الاسلحة الى
المسلمين البوسنيين والى الكروات خارقة بذلك الحظر على توريد الاسلحة الذي اقرته الامم
المتحدة في ايلول/سبتمبر 1991 ضد يوغوسلافيا السابقة .واضافت الصحيفة الاميركية نقلا عن دبلوماسيين غربيين وعن مسلمين في
ساراييفو ان طائرة شحن من طراز بوينغ 747 حطت في الرابع من ايار/مايو في مطار زغرب وهي تحمل اربعين
حاوية اعلن عنها بوصفها "مساعدات انسانية" ولكنها كانت تحتوي متفجرات وصواعق ومواد تدخل في صناعة المدافع ونخائر
واوضحت الصحيفة ان ثلث الحمولة كان من حصة كرواتيا والثلثين الباقيين نقلا الى المسلمين في شاحنات حكومية .
ونقلت الصحيفة عن مصدر عسكري بوسني "انها اول قافلة اسلحة معروفة بهذه الاهمية منذ بدء الحرب. انها الاولى ونأمل الحصول
على اخرى ."
وذكرت الصحيفة نقلا عن مسؤولين غربيين ان هذه الاسلحة تضاف الى اسلحة اخرى تم ادخالها في الماضي بطريقة سرية الى
البوسنة مثل البنادق الحربية البرازيلية او بنادق مضادة للدبابات من صنع تشيلي قادمة من جهة مجهولة .
</TEXT>
</BODY>
</DOC>
```

Figure 4: Sample document from TREC 2001 collection [30].

(iii) Substitute the last ى by ي

6.4. Elimination of Stop-Words. Stop-words are those words that occur frequently in the document. These words give no hint to the document content in which they appear. Stop-words removal is mandatory prior to submitting text to be processed by an ATC system in order to reduce both time and cost. Hence a list of stop-words is created, which is then applied to the indexed terms to be eliminated. However, for an ATC system there is no prominent stop-words list that could be used in such systems. Consequently, for the experiment, the same stop-words list used in [32] was used here. Table 1 provides some examples of Arabic stop-words.

6.5. Stemming Text. The text stemming process helps in reducing the various inflectional derivational words forms to a uniform called the stem [32]. For instance, the terms, "work," "works," "working," "worked," and "worker" are derived from the "work" stem. Table 2 shows an example of different Arabic words derived from the same root. The word root is gained by eliminating some or all the word suffixes attached to it. In the ATC system, terms are grouped together that share the same stem or root, which effectively raises the number of matched documents to the user query. Furthermore, there is an overall improvement in the ATC performance due to the reduction in the dictionary size as a result of the stemming process [33].

In this paper, for stemming purpose we followed the same stemming steps in [33] using Light10 stemmer, as follows:

(1) Remove "و" ("and") for Light2, Light3, Light8, and Light10 if the remainder of the word is three or more characters long
(2) Eliminate the definite articles that leave the remaining word with more than or equal to two letters
(3) Keep words with a length of two or more letters after suffixes removal which appears in the list; remove one at a time in order from right to left

Table 3 shows the list of strings that should be removed. Note that the conjunction and definite articles are the prefixes shown in the table. No elimination is done for the

Table 1: Examples of Arabic stop-words.

Arabic word	English meaning
في	In
من	From
إلى	To
على	Over
عن	About

strings that deemed an actual Arabic prefix in Light10 stemmer.

Table 4 shows an example of affixes in Arabic word.

7. Document Representation

Each document in the study dataset was represented by a vector t_i with the term as the attribute and the attribute value as its TFIDF weight [34], which is a statistical way of determining the relevance of a word to a document in a corpus. The most commonly used method to weight a term is the (TF.IDF) weighting, because it considers the attribute. With this weighting scheme, setting the weight of the term I in the document d is proportional to the number of times the term appears in the document, the Term Frequency (TF), and inversely related to the total number of documents in which the term appeared from the corpus, the Inverse Document Frequency (IDF).

The TFIDF weighting method assigns a weight to the number of term occurrences in a document by disregarding its relevance in case it appeared in most of the documents, especially when the term is assumed to possess little discriminating power:

$$w\_i = tf\_i \cdot \log\left(\frac{N}{n}\right). \quad (4)$$

7.1. Construction of the Three Classifiers. In this experiment, the Arabic dataset documents were categorized using the following classifiers: KNN, NB, and DT in two forms, the full word (without stemming) and the stem word (full word stemmed by light10 stemmer).

7.2. Evaluation and Comparison of Classification Quality. Two measures are mainly used to evaluate the quality of the output of a classifier, namely, the f-measurement and accuracy [35]. In classification problems, the evaluation is generally represented in the form of a confusion matrix. The matrix contains the number of instances that are correctly and wrongly classified for each class.

In practice, the most widely used evaluation metric is the accuracy (ACC) rate. It represents the classifier efficiency based on the proportion of the number of correctly predicted instances the classifier made. The classifier accuracy is calculated as

$$\mathrm{ACC} = \left(\frac{(\mathrm{TP} + \mathrm{TN})}{(\mathrm{TP} + \mathrm{TN} + \mathrm{FP} + \mathrm{FN})}\right). \quad (5)$$

Table 2: Sample showing different words derived from the same root, *Ktb* كتب.

Word in Arabic	Meaning in English	Root (stem) in Arabic	Root (stem) in English
مكتب	Office	كتب	*Ktb*
كاتب	Writer	كتب	*Ktb*
مكتبة	Library	كتب	*Ktb*
مكتوب	Written	كتب	*Ktb*

Table 3: List of prefixes and suffixes eliminated by Light10.

Prefixes	Suffixes
وال، بال، كال، فال، لل، و، ال	ها، ان، ات، ون، ين، يه، ية، ه، ة، ي

Table 4: Examples of affixes in Arabic word (يرونهم, ليخادعونهم).

Postfix	Suffix	Root	Prefix	Antefix
هم	ون	يرى	ي	ل
هم	ون	خدع	ي	ل
Pronoun meaning (they)	Termination of conjugation	يرى meaning (see) and خدع meaning (deceive)	A letter meaning the tense and the person of conjugation	Preposition meaning (to)

Table 5: Performance of the three classifiers without stemmer.

Classifiers	Number of features without stemmer	Accuracy (%)
DT	91756	90.2985
KNN	91756	26.119403
NB	91756	33.830846

Table 6: Performance of the three classifiers with stemmer.

Classifiers	Number of features before stemmer	Number of features after stemmer	Accuracy (%)
DT	91756	46167	93.7811
KNN	91756	46167	26.368159
NB	91756	46167	35.074627

8. Results

A comparison of the three classifiers was conducted in respect of accuracy and the number of features selected with and without the use of stemming in the preprocessing phase. Tables 5 and 6 show the results for the three classifiers with and without stemmer, respectively.

The tables show that, without a stemmer, DT outperformed KNN and NB achieving 90% accuracy as compared to 33.83% and 26.11%, respectively. When a stemmer was included in the preprocessing phase, all three classifiers improved their performance, and again, DT produced the best result with 93% as compared to NB with 35% and KNN with 26.36%. Thus, the use of a stemmer improved the accuracy of all three classifiers. Furthermore, the tables show that the use of a stemmer also reduced the number of features around 50% by the classifiers. Figure 5 provides a graphical illustration of the results, by which we can conclude that the number of features has effect on the NB and KNN performance. KNN when using all features got accuracy of 26.12, while when using stemmer the performance was not satisfying, with accuracy of 26.36%. On the other classifier of NB the stemmer enhances around 1.8% but comparing with DT the performance was better. We can conclude that the DT can be used for huge features better than NB and KNN.

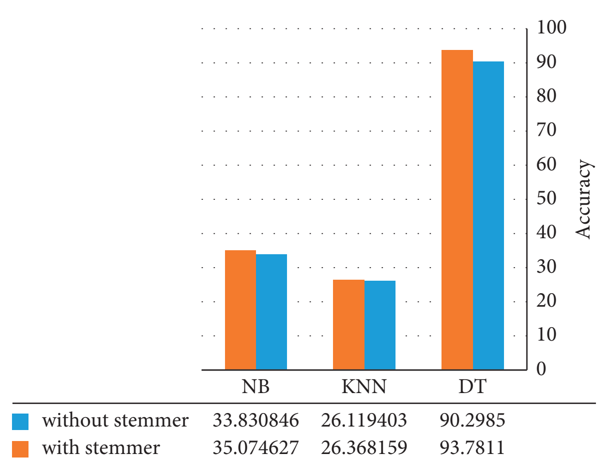

Figure 5: Accuracy of the three classifiers with/without stemmer.

The result shows that the decision tree with light stemmer was the best accuracy rate for classification algorithm with 93%.

9. Conclusion and Future Work

In this paper, prior to developing our proposed method, we reviewed several previous studies that contributed to improving our understanding of the study problem, namely, the classification of Arabic text, and potential solutions. Given the vast amount of information in Arabic that is available online, and which continues to grow, the main aim of this study was to save the effort and cost of both users and developers in searching for and using such data. In this work, we address the weakness of classifiers used for TC before as KNN, NB, and DT. The main weakness of the classifier algorithms is being poor when holding a huge number of features. Based on our experimental outcomes, we find that DT with stemmer can improve efficiency and outperform other classifiers compared to this work. However, the dimensionality of the terms without light stemming is the primary weakness in preprocessing phase, where there is a need for feature selection to fill the gap in the number of huge terms as a future work. We offer future work to improve text classifier with deep reinforcement Q-learning combined with our proposals. We also recommend the use of other classification criteria not used here in this work.

Data Availability

The data are available at https://catalog.ldc.upenn.edu/LDC2001T55 and are not free to access.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this study.

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Research Article

A Fuzzy Logic and Multilevel Analysis-Based Evaluation Algorithm for Digital Teaching Quality in Colleges and Universities

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To address the limitations of the university digital teaching quality assessment algorithms as well as the large evaluation mistakes in the existing algorithms, this paper presents a unique university digital teaching quality evaluation method based on multilevel analysis. First, the existing state of digital teaching quality evaluation in colleges and universities is studied to develop an evaluation index for digital teaching quality. Then, to identify and compute the weight of digital teaching quality indicators, an index weight evaluation matrix is built and the weight of digital teaching quality assessment indicators is plotted using a multilevel structure tree model. Then, from the top to the bottom of the tree, this paper computes the hierarchical ranking of assessment indicators. Additionally, this paper computes the membership degree of index evaluation, normalises the evaluation indicators, and completes the digital teaching quality assessment with the digital teaching confidence calculation. The experimental results demonstrate that the proposed method's digital teaching quality assessment index has a high degree of accuracy and low evaluation error.

1. Introduction

Teaching quality evaluation describes the educational evaluation, where teaching is used as the evaluation object. It is the cornerstone and core of the entire educational assessment. Specific mathematical objectives, instructional norms, and standards are used to assess teaching quality. These include systematic detection and assessment of teaching and learning, assessing the teaching effect and the degree of realization of teaching objectives and making corresponding value judgements to enhance the teaching process using scientific and realistic techniques [1]. Currently, most Chinese colleges and universities are equipped with the latest hardware and software [2]. In the teaching process, we may actively employ contemporary teaching facilities, which can considerably enhance teaching quality. Under the premise of the same basic mathematics reform, different teachers still have their own teaching styles. Therefore, teachers' classroom teaching style has always affected the quality of the overall teaching process. In order to distinguish the differences in classroom teaching, there are not good enough scientific methods to encourage the excellent and make joint policies for the backward. Therefore, when evaluating a teacher's performance, completing the class hour index and the homework specified by the school and the teaching quality and effect have become a mere soft index, which greatly frustrates teachers' enthusiasm. At the same time, the classroom is where students learn the most, and classroom teaching is critical to enhance overall teaching quality [3]. The goal of developing a fair digital teaching quality rating system is to accurately discern between teacher quality and the white body benefits of digital education. Higher education is a critical component of Chinese education. The quality of higher education has a direct influence on the quality of higher-level skills and the level of growth of the national economy. The continuous enrollment expansion has gradually revealed the contradictions in teaching and scientific research equipment, quality and quantity of teachers, infrastructure construction, and other aspects of ordinary colleges and universities. The improvement of the gross enrollment rate has brought about the quality of students, which poses a potential threat to the quality of higher education [4].

With the increasing popularity of higher education in China, digital teaching has aided in the transformation of the whole educational system. The quality supervision and evaluation mechanism of digital teaching are important measures to ensure teaching quality [5]. It is critical to develop a fair and scientific method for monitoring and evaluating the quality of digital instruction. As a result, researchers in this sector have conducted a significant amount of quality evaluation study and produced positive outcomes. The authors in [6] presented a method for evaluating multimedia education quality using grey correlation analysis and neural networks. This technique creates a multimedia quality evaluation method based on grey correlation analysis and neural networks to address several flaws in multimedia quality evaluation. This technique creates a multimedia quality evaluation method based on grey correlation analysis and neural networks to address several flaws in multimedia quality evaluation. They use grey correlation analysis to calculate the weight of the multimedia teaching quality assessment index and a neural network to construct the classifier of multimedia teaching quality grade. Finally, various multimedia teaching quality evaluation methodologies are used to conduct the simulation test. The findings reveal that the multimedia teaching quality of the suggested technique is greater than 95%. In comparison, the accuracy rate of the comparison method's multimedia teaching quality rating is less than 95%. Simultaneously, the modelling efficiency of multimedia teaching quality evaluation has improved dramatically. It introduces a novel study approach for assessing the quality of multimedia education; however, it takes into account less digital teaching quality index data and has certain drawbacks. Zhang et al. [7] developed a supplemental teaching quality evaluation approach based on active learning support vector machine (SVM). This study provides an assessment index system for classroom teaching quality, taking into consideration the existing situation in a number of ways. A model for measuring classroom teaching quality is created using the active learning support vector machine. Experiments are done on the collected data set pertaining to a university's teaching quality. The experimental results demonstrate that the proposed evaluation model outperforms existing evaluation models in terms of accuracy and efficiency, and that it may produce superior teaching quality assessment outcomes in colleges and universities. This approach is straightforward, and its productivity is high, but there are few signs for the one-sided study object. Li et al. [8] offered a data mining-based methodology for evaluating university teaching quality. To begin, the model examines and analyses the current literature on college teaching quality assessment and determines the elements that influence college teaching quality evaluation. The model then gathers information on the elements that influence college teaching quality, assigns a grade to college teaching quality based on expert judgement, and creates a learning sample for college teaching quality evaluation. Finally, a data mining-based technique is presented to train the learning samples to construct the university teaching quality rating model using the BP neural network. Specific examples are used to illustrate the benefits of the university teaching quality model. The findings show that data mining may be used to describe differences in university teaching quality grades and provide high-precision university teaching quality evaluation results. Furthermore, compared with previous methods, the college teaching quality evaluation error is far lower, which has significant benefits. However, the assessment of digital teaching quality is woefully inadequate and has to be improved.

In light of the shortcomings of the previous techniques, this work offers a study of a multilevel analysis-based algorithm for evaluating digital teaching quality in colleges and universities. The following are the precise technical procedures examined in this paper:

Step 1. I examine the present state of digital teaching quality assessment in colleges and universities and calculate the digital teaching quality evaluation index in colleges and universities based on the existing scenario.

Step 2. To establish the weight of digital teaching quality evaluation indicators, I create an index weight evaluation matrix.

Step 3. I design a multilevel structure tree model and then establish that the assessment indicators are ranked from top to bottom hierarchically. I also compute the evaluation indicators' membership degree, normalise the evaluated indicators, and finish the evaluation of digital teaching quality by calculating the confidence of digital teaching indicators.

2. Evaluation Index and Weight of Digital Teaching Quality

2.1. Current Status of the Digital Teaching Quality Evaluation in Universities. Personal experience, use of students' scores, teachers' self-evaluation, comprehensive scoring of leaders, and then seeking the average score, or subjectively scoring directly through some characteristics in the teaching process, are still used to evaluate digital teaching quality in colleges and universities (such as outstanding teaching contributions and teaching accidents). This means that the manual level is based on qualitative analysis. However, due to the large amount of data collected and statistically summarized, manual teaching quality evaluation methods often make information timeliness and accuracy challenging to guarantee. Such evaluation method still relies on personal experience and focuses on qualitative analysis, lacking objectivity, and quantitative analysis. Especially when making a comprehensive evaluation of teachers' long-term work, it is neither comprehensive nor in-process to evaluate a specific period or some prominent characteristics [9].

To begin with, several indicators are frequently used in the evaluation of digital teaching quality in colleges and universities, and the indicators used should properly represent the activity of teachers. We must not make a partial and comprehensive assessment based on the current state of one or more indicators. This assessment is unfair and unscientific since it only evaluates the remarkable contribution of teaching in some areas or only stresses rare teaching errors [10].

Second, the school assesses the quality of digital instruction in colleges and universities by rating students for teachers, combining the scores of leaders for teachers and then using statistics to arrive at an average score. This assessment technique appears to be "all-encompassing," yet it is not. The correlation and mutual relevance of numerous indicators are ignored in this technique. Because not every metric is equally important in the teaching process, and from an empirical standpoint, using manual techniques to determine the scores of digital teaching quality evaluation in colleges and universities is time-consuming and tedious. Still, it does not achieve the objective and fair evaluation of digital teaching quality.

Finally, the weighting mechanism and assessment index are unscientific. Two characteristics of an assessment system have the most influence on the evaluation object. On the one hand, whether the evaluator can objectively evaluate the research object; nevertheless, given the current technical conditions, the appraiser's ability to evaluate the evaluation object objectively is not guaranteed [11].

On the other side, it is to determine whether the index system and its weight are fair. In this regard, the index system and its weight of certain evaluation systems are introduced to the system during system construction based on user needs, which cannot be altered during user usage and lack flexibility.

2.2. Evaluation Index of Digital Quality Teaching. I applied the fuzzy comprehensive evaluation theory [12] to create a digital teaching quality assessment index based on the current state of digital quality evaluation. How to appropriately estimate each assessment index's weight is a crucial topic in both theory and practise of fuzzy comprehensive evaluation. It provides assessment results based on numerous criteria (or many judges) that evaluate something, and it combines the evaluation findings [10] of the various elements (or multiple judges).

Suppose U and L represent two limited theories of college digital quality evaluation, respectively,

$$\begin{aligned} U &= \{u_1, u_2, \cdots, u_n\}, \\ L &= \{l_1, l_2, \cdots, l_n\}. \end{aligned} \tag{1}$$

Among them, U represents a collection of digital quality evaluation factors (or judges) and L denotes the collection of college digital quality evaluation comments (or the collection of evaluation results). For the digital quality assessment list factors of universities u_{in}, the fuzzy evaluation given for something uses a fuzzy set of digital quality evaluation of a university on the comment set (or evaluation result set) as follows:

$$U_m = (u_{i1}, u_{i2}, \cdots, u_{in}). \tag{2}$$

Among them, $0 \le u_{ij} \le 1$, where $i = 1, 2, \cdots, n$ and $j = 1, 2, \cdots, m$.

Then, the evaluation matrix of the digital quality evaluation index P can be obtained as follows:

$$P = \begin{bmatrix} u_{11} & u_{12} & \cdots & u_{1n} \\ u_{21} & u_{22} & \cdots & u_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ u_{n1} & u_{n2} & \cdots & u_{nn} \end{bmatrix}. \tag{3}$$

The evaluation index of university digital quality mainly adopts matrix method for evaluation, and at the same time, it must meet the conditions of formula 3, in which U and represents fuzzy sets $(x_1/(u_1, x_2/u_2, \cdots, x_n/u_n))$ or a vector $X = (x_1, x_2, \cdots, x_n)$, and $\sum_{i=1}^{n} x_i \ge 0$ represents the comprehensive evaluation result of the indicator or a vector. It was obtained in accordance to the above calculation and determines of college digital teaching indicators [13].

2.3. Weight Calculation of Digital Teaching Quality Evaluation Index in Universities. After obtaining the digital teaching indicators from the aforementioned colleges, the weight [14] of the above assessment indicators must be calculated by creating an online teaching quality evaluation matrix. The evaluation matrix is expressed by R. The above teaching quality evaluation indicators have a subset R_i. In this paper, I set all teaching quality influence factors as R and construct the evaluation matrix of $T \times \mathrm{V}$ in the feasible field of influence factors, represented by R,

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}. \tag{4}$$

Through the evaluation of digital teaching quality, the calculation process is as follows:

$$S' = Q \cdot R = (q_1, q_2, \ldots, q_m) \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} = (s_1', s_2', \ldots, s_n'). \tag{5}$$

In order to improve the accuracy of the impact of this research on the digital teaching quality, the membership and evaluation membership value are repeatedly calculated, and the evaluation value of all the influence indicators of the digital teaching quality is obtained, which is denoted by SS. Quantitative fuzzy comprehensive evaluation results of online classroom teaching quality can be calculated as follows:

$$S \times N = (s_1, s_2, \ldots, s_n)\begin{bmatrix} n_1 \\ n_2 \\ \vdots \\ n_n \end{bmatrix}. \quad (6)$$

In the weight determination and calculation of digital teaching quality indicators in universities, the framework index weight evaluation matrix determines the weight of digital teaching quality evaluation indicators, which lays the foundation for the subsequent evaluation.

3. Implementation of College Digital Teaching Quality Evaluation Algorithm Based on Multilevel Analysis

Multilevel analysis is a frequently used and essential approach in fuzzy mathematics. It consists of a number of assessment indicators as well as the weights assigned to each indication across all indicators. The term "multilevel" refers to the hierarchy of indicators rather than the assessment indicators themselves. In the form of a tree structure, these indicators are interconnected [15]. The fundamental structure of these indicators is depicted in Figure 1.

A complicated problem is divided into numerous components using this structural paradigm (or elements). Each component can also be broken down into multiple groups, each with its own hierarchy. These levels are divided into three groups in this study:

(a) *Target Layer*. It is the assessment objective of the evaluation object and reflects the system evaluation objective or the predefined aim or outcome of the analytical problem. Only one target or element may be found at the highest level at this level.

(b) *Criteria Layer*. It depicts the goal's intermediary connection, such as the plan, measurements, and tactics used to attain it. It is a set of indications or rules for evaluating anything. The criteria layer, the subcriterion layer, each subcriterion, and the link between the criterion layer are all possible levels. The subcriterion layer depicts the relationship between the preceding and subsequent layers. Each level can have many criteria or components, with sublevels reporting to the preceding level's criterion.

(c) *Index Layer*. This layer shows the objective's intermediate connection, as well as the solutions, measurements, methods, and other options for accomplishing the goal. You can have many schemes or elements at this level, which is the lowest level.

In the digital teaching quality evaluation, after determining the digital teaching indicators and weights, the multilevel analysis method is used to judge the key digital teaching indicators. I set the importance indicator data in the index collection as B_{ij} and then carry on it the judgement $n(n-1)/2$. I define the membership of the multilevel evaluation index as follows:

$$b_i = \sum_{i=1}^{m} \omega_i \times s_{ij} = \min\left\{1, \sum_{i=1}^{m} \omega_i \times s_{ij}\right\}. \quad (7)$$

In formula, $i = 1, 2, \cdots, m$ and $j = 1, 2, \cdots, n$ indicate a fuzzy addition, i represents the i evaluation factor of the n evaluation factors, j represents the j rating of the m evaluation rating, and b represents the membership of the j evaluation rating.

According to [16], the multilevel analysis is evaluated by determining the hierarchy of the evaluation indicators. Identifying the hierarchical ranking of evaluation metrics is performed in a high-end order. The multilevel structure of digital teaching quality evaluation is shown in Figure 2:

In Figure 2, there are m indicators in layer K, and the weight of the total digital teaching quality evaluation is k_1, k_2, and k_3. At this time, the K layer contains n indicators $(\underline{k}-1)$, sorted in this order. If the index k-1 is independent of the index $(k-1)_j$, the value is 0; then, the evaluation result is as follows:

$$w_i^{(k-1)} = \sum_{j=1}^{m} w_j^{(k)} w_{ij}. \quad (8)$$

With the digital teaching quality evaluation error, further processing is first normalized as follows:

$$w_i = \frac{\overline{w_i}}{\sum \overline{w_j}}. \quad (9)$$

The confidence of the normalized evaluation results is calculated to determine that whether or not the final evaluation results are credible as follows:

$$\vartheta^2 = \frac{\sum\left(b_{ij}^{k} - \overline{b_{ij}^{k2}}\right)}{m}. \quad (10)$$

In the formula, ϑ^2 represents the positive distribution, b_{ij}^{k} is the overall variance, and b_{ij}^{k2} represents the overall standard deviation.

In the digital teaching quality evaluation, I first design the multilevel structure tree model and then determine the hierarchy of the evaluation indicators from the order of the evaluation. Further, I calculate the membership of the evaluation indicators through the confidence of digital teaching indicators and finally compute the evaluation of digital teaching quality evaluation.

4. Experimental Analysis

4.1. Experimental Protocol Setup. An experimental study is carried out in this work to validate the performance of the suggested assessment technique. The experiment used English majors at a university for a year as the research subject. The class had a total of 80 pupils. Multimedia equipment was used to teach the English majors in the class. In a week, multimedia instructors taught three professional classes. The grade served as the control group. The teaching of professional courses in this class is not done in multimedia for students in class B. The efficacy

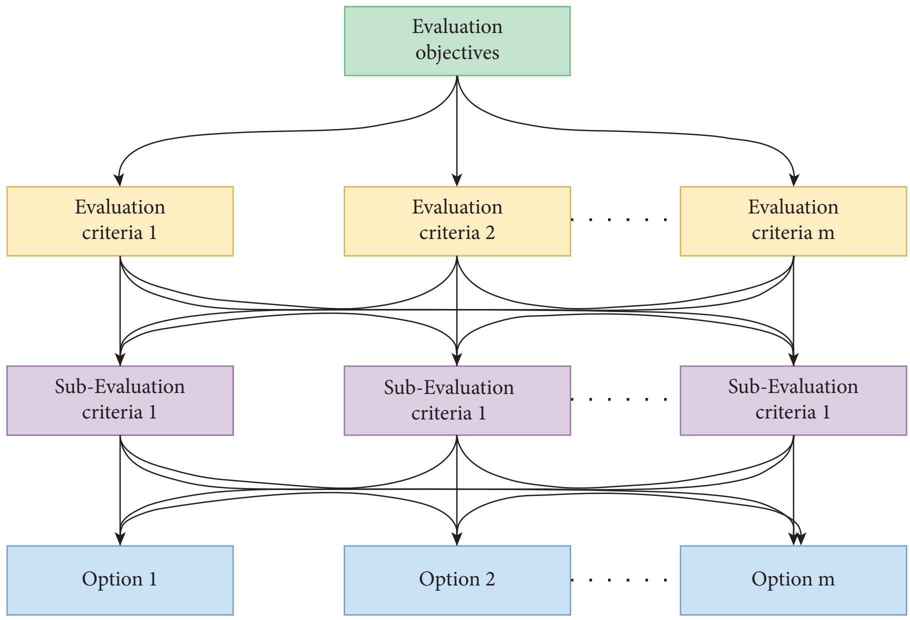

FIGURE 1: Tree structure diagram of multilevel analysis.

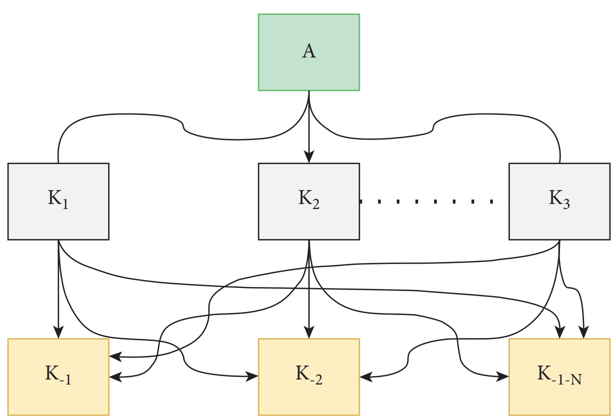

FIGURE 2: The multilevel structure of digital teaching quality evaluation.

of the evaluation technique is proven by assessing the academic accomplishments of classes A and B over the course of one semester. An experimental study is carried out in this work to validate the performance of the suggested assessment technique. The experiment used English majors at a university for a year as the research subject. The data collected in the experiment are processed by professional software to verify the experiment's correctness.

4.2. Experimental Index Design. The experiment's performance analysis is influenced by the indicators used in the experiment. As a result of the comparison technique, the accuracy of evaluation indicators and the error of quality assessment are used as experimental indicators in this paper's experimental analysis. The experiment's middle school kids' accomplishment data have been provided, and the experimental analysis is based on the students' successes.

4.3. Analysis of Experimental Results. The proposed approach, multimedia teaching quality evaluation based on grey correlation analysis and neural network, and the correctness of the data mining algorithm were used to test the method's performance. Table 1 summarises the findings.

Table 1 and Figure 2 illustrate the accuracy results of the suggested technique based on grey correlation analysis and the data mining algorithm-based college teaching quality rating model. The accuracy in the sample evaluation data is approximately 96 percent, the accuracy based on grey correlation analysis and multimedia teaching quality evaluation is approximately 89 percent, and the college teaching quality evaluation model based on the sample evaluation data is approximately 85 percent. The determined indications of this approach, on the other hand, are more accurate. This is due to the method's usage of fuzzy theory, which increases our method's efficacy. Precision comparison results through different method evaluation indexes (%) are shown in Figure 3.

Table 1: Analysis of precision comparison results determined by different method evaluation indexes (%).

Number of index determination/times	The proposed method	Multimedia teaching quality evaluation based on grey association analysis and neural network	Evaluation of college teaching quality based on the data mining algorithm
10	95	89	85
20	96	88	85
30	95	88	84
40	95	85	86
50	95	85	85
60	96	85	84
70	96	84	80
80	95	86	82
90	96	85	81
100	95	84	81

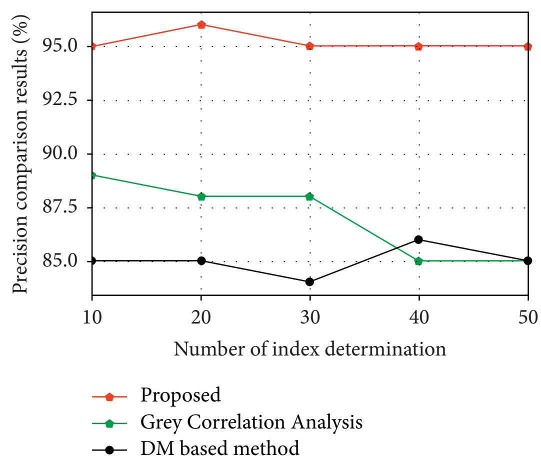

Figure 3: Precision comparison results through different method evaluation indexes (%).

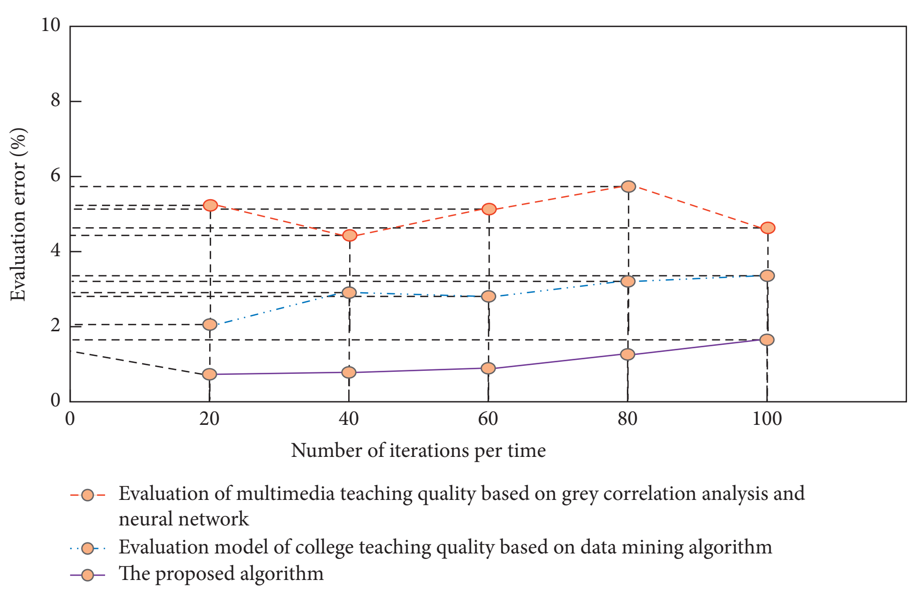

Figure 4: Error results of the sample evaluation data evaluation.

The proposed model, grey correlation analysis, neural network multimedia teaching quality assessment, and college teaching quality evaluation model were used to evaluate the sample evaluation data evaluation error. Figure 4 depicts the results of the sample evaluation data evaluation error.

Figure 4 shows that the proposed approach, grey correlation analysis and neural network multimedia teaching quality assessment, and the college teaching quality evaluation model based on data mining algorithm are distinct. The suggested approach has the lowest sample evaluation

Table 2: Comparison results with respect to consistency examination (CR) values.

Methods	CI	RI	CR
Proposed method	0.00843	0.845	0.01
Neural network	0.4528	0.645	0.67
Data mining	0.5142	0.598	0.84

error, which is always less than 2%, while the other two methods are always greater. This is because the proposed approach calculates the membership of the index evaluation, completes the evaluation of the quality of digital teaching indicators, and then enhances the proposed method's efficacy.

Table 2 reveals that only the consistency examination (CR) score of this approach is less than 0.1 among the three methods. In the university teaching quality evaluation model based on data mining algorithms, CR values are all above 0.1. This indicates that the technique and the actual evaluation findings are the most consistent, indicating that the method is successful.

5. Conclusion

This paper proposes a multilevel analysis-based digital teaching quality evaluation model. This paper created a hierarchical tree-based model based on the digital teaching quality index and the weight of the assessment matrix. In my proposed method, I first determined the evaluation's membership and then normalised the digital teaching index confidence before concluding the digital teaching quality assessment. The experimental findings demonstrate that the digital teaching quality evaluation indexes are very accurate while being difficult to implement [16].

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

A Method of Recommending Physical Education Network Course Resources Based on Collaborative Filtering Technology

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Through the current research on e-learning, it is found that the present e-learning system applied to the recommendation activities of learning resources has only two search methods: Top-N and keywords. These search methods cannot effectively recommend learning resources to learners. Therefore, the collaborative filtering recommendation technology is applied, in this paper, to the process of personalized recommendation of learning resources. We obtain user content and functional interest and predict the comprehensive interest of web and big data through an infinite deep neural network. Based on the collaborative knowledge graph and the collaborative filtering algorithm, the semantic information of teaching network resources is extracted from the collaborative knowledge graph. According to the principles of the nearest neighbor recommendation, the course attribute value preference matrix (APM) is obtained first. Next, the course-predicted values are sorted in descending order, and the top T courses with the highest predicted values are selected as the final recommended course set for the target learners. Each course has its own online classroom; the teacher will publish online class details ahead of time, and students can purchase online access to the classroom number and password. The experimental results show that the optimal number of clusters k is 9. Furthermore, for extremely sparse matrices, the collaborative filtering technique method is more suitable for clustering in the transformed low-dimensional space. The average recommendation satisfaction degree of collaborative filtering technology method is approximately 43.6%, which demonstrates high recommendation quality.

1. Introduction

The Internet era, supported by big data and Internet of things, is a period of rapid development within the domain of knowledge and information curriculum resources. The curriculum resources for sports health and rehabilitation are also more abundant and diverse [1]. Reasonable, scientific, and effective integration and utilization of curriculum resources are bound to be beneficial to the improvement of the construction level of sports health and rehabilitation. Therefore, it is very important to attribute reputation to sport health and rehabilitation and strengthen their integration with curriculum resources [2]. From the perspective of the composition of general curriculum resources, this includes mainly four main parts: (a) teacher team; (b) students; (c) teaching materials; and (d) social resources [3].

With the popularization of the Internet, traditional training schools began turning to the front in 2000, and online learning tools, platforms, and content began emerging in large numbers. "Smart Education" was proposed by Peng et al. in a speech in 2008. Around 2012, online learning ushered in a spurt of growth and professional online learning platforms were born in large numbers, mainly Internet companies (e.g., Ape Guidance, Job Gang, and VIPKID), with diversified content formats. In 2020, due to the impact of the new crown pneumonia epidemic, that is, COVID-19, all universities and education institutes across the country and globe have started online learning management systems [4]. Moreover, employers in various industries also start working from home. Since then, China's online learning began to enter the world stage [5].

Sheshasaayee et al. conducted an in-depth study of the Moodle learning management system in 2017. Moodle not only provides rich learning resources but also has a learning record tracking function, allowing lecturers to freely choose the teaching mode according to the actual situation of the learner. At the same time, learners can also choose courses freely to achieve the purpose of personalized teaching [6]. Jones et al. studied the impact of the Knewton-based adaptive learning recommendation engine on learning effects in 2018. The Knewton platform provides powerful functions for learners and classroom-related analysis data to predict their future performance, enabling lecturers to achieve differentiated education based on individuals. Learners obtain personalized curriculum recommendations through systematic analysis and assessment of knowledge and ability, which provides the possibility to realize automated and personalized learning [7]. CIRCSIIVI-Tutor of the University of Illinois in the United States can support personalized services for distance online education and can help to solve learners' problems by establishing an intelligent system based on language dialogs.

This paper proposes a method for recommending physical education network course resources based on collaborative filtering technology. The user-based collaborative filtering method is a way to find out similar neighbors of the target user by calculating the similarity between user behavior and other user behavior (ratings, comments, etc.). Then, the interest or preference of the target user is predicted based on the interest or preference of similar neighbors to provide the user with suggestions. This article introduces an optimized theoretical model, a better collaborative filtering technology for a personalized recommendation of physical education online course resources. The proposed method pays attention to discussing the structure of the model and the implementation of the corresponding scoring mechanism and algorithm and analyzes the three important technologies in the personalized learning resource recommendation model. It is observed that e-learning-related personnel can effectively use collaborative filtering technology in the search process, to improve the efficiency of the personalized recommendation system of learning resources. The principal contributions of our research are highlighted as follows:

- We design a novel method for recommending physical education network course resources based on collaborative filtering technology
- User-based collaborative filtering is to find out the similar neighbors of the target user by calculating the similarity between user behavior and other user behavior
- pay attention to discussing the structure of the model and the implementation of the corresponding scoring mechanism and algorithm and analyze the three important technologies in the personalized learning resource recommendation model

The rest of the paper is organized as follows: in Section 2, we briefly discuss the related literature review in terms of collaborative filtering technology. In Section 3, physical education teaching network course resource recommendations are described. In Section 4, we describe the experimental study and results analysis. Finally, Section 5 illustrates the final thoughts and several directions for future research and investigation.

2. Collaborative Filtering Technology

In this section, we offer an overview of the basic terminologies including calculation of content, functional interests, and prediction of the interest degree.

2.1. Content Interest Calculation. The number of views can reflect the user's degree of interest in different data. Assume that the user u interest in Web big data O increases as the number of times that O is viewed by other users increases, and at the same time, it shows an inversely decreasing trend with the frequency of browsing. Then, you can use the TF-IDF algorithm, combined with the number of browsing times to obtain the user's interest in big data [8].

TF-IDF is an algorithm for estimating the importance of words to a document in a document collection. It can predict the importance of a target in a dimensional space. Assuming that any user in the recommendation system is regarded as a document, the big data browsed by the user is a certain vocabulary in the document, and the user's preference for the data is obtained according to the number of occurrences of the vocabulary.

The reference assumes that, in the recommendation system, there is a set $u' = \{u_1', u_2', \ldots, u_x'\}$ with χ users and a set δ with $o' = \{o_1', o_2', \ldots, o_\delta'\}$ big data. The number of times the user $u'_{i'}$ views the data $o'_{j'}$ is $R_{i',j'}$, and the importance of the web data to the user is calculated by the word frequency $TF_{\chi,\delta}$:

$$\mathrm{TF}_{\chi,\delta} = \frac{\mathrm{R}_{i',j'}}{\sum_{k\in 0} R_{i',j'}}. \tag{1}$$

Here, $\sum_{k\in 0} R_{i',j'}$ represents the sum of the number of times the user browses all the data in the collection [9]. If the number of users who have viewed the data $o'_{j'}$ is represented as χ_{oj}, the importance of the data $o'_{j'}$ to all users can be obtained by the reverse document frequency $I\ DF_{oj}$:

$$\mathrm{IDF_{oj}} = \lg \frac{x}{x_{oj}}. \tag{2}$$

Therefore, the definition formula of the user's interest in the data content is obtained:

$$\mathrm{C}_{\chi,\delta} = TF_{\chi,\delta} \times I\ DF_{oj} = \frac{R_{\chi\delta}}{\sum_{k'\in 0} R_{\chi k'}} \times \lg \frac{x}{x_{oj}}. \tag{3}$$

The interest degree values of the user $u'_{i'}$ for all the data in $o' = \{o_1', o_2', \ldots, o_\delta'\}$ constitute $u'_{i'}$ interest degree vector $C_x = (C_{x,1}, C_{x,2}, \ldots, C_{x,m})$.

2.2. Functional Interest Calculation. There are big differences in the number of users browsing different types of data. The number of views can be increased indefinitely. At the same time, users are not necessarily uninterested in data with zero views, and they may have no experience in using it [10]. To reflect the user's interest more scientifically through the number of views and avoid mass information annihilating the user's interest in other data. This article defines an initial value for the data that the user has not browsed and introduces the Sigmoid function to standardize the number of browsing times to obtain the user's interest in the data function.

The Sigmoid function is a common S -type function, and its definition is as follows:

$$S(x') = \frac{1}{1 + e^{-x}}. \tag{4}$$

This function is continuous, smooth, and monotonic and its value range is $(0, 1)$, and it is symmetric about the center of $(0, 0.5)$, which is a threshold function with better performance. In the interval $-\infty, 0$, the nonlinear growth trend of the block after the slowness appears, and the growth trend of the $0, +\infty$ in the interval is fast first and then slow.

In the recommendation system, the calculation formula for the functional interest ${}_{Fi'}{}^{\prime}_{j'}$ of the user $u'_{i'}$ to the data $o'_{j'}$ is as follows:

$$_{Fi'}{}^{\prime}_{j'} = \frac{1}{1 + e^{-\left({}_{Ri'}{}^{\prime}_{j'} - R'_{i'}\right)}}. \tag{5}$$

The value of formula (5) is in the range of $0, 1$, which shows a nonlinear and monotonous increasing trend with the increase of the number of browsing. $R'_{i'}$ indicates the average number of times the user $u'_{i'}$ views all the data viewed. This formula more intuitively reflects the user's interest, and in the ${}_{Ri'}{}^{\prime}_{j'} = 0$ situation, defines the initial value for the functional interest.

From formula (5), it can be concluded that the functional interest degree of the user $u'_{i'}$ for all the data in $o' = \{o'_1, o'_2, \ldots, o'_\delta\}$ constitutes the functional interest vector $F'_{i'} = \{{}_{Fi'}{}^{\prime}_{1}, {}_{Fi'}{}^{\prime}_{2}, \ldots, {}_{Fi'}{}^{\prime}_{m}\}$ of the user $u'_{i'}$.

2.3. Prediction of the Comprehensive Value of Interest Degree. After obtaining the user content and functional interest, select the top ϕ users with the highest similarity to the target user $u'_{a'}$ to form the nearest neighbor set $G_{a'}$, and use the following formula to predict the interest of the target user $u'_{a'}$ in the target data $o'_{q'}$:

$$\text{pred}\left(u'_{a'}, o'_{q'}\right) = \bar{F}'_{a'} + \frac{\sum_{u_{b'} \in N'_{a'}} {}'S_{a'b'}{}^{\prime}\tilde{\text{A}}\text{—}\left(\text{F}_{b'a'}{}^{\prime} - \bar{\text{F}}'_{a'}\right)}{\sum_{u_{b'} \in N'_{a'}} {}'S_{a'b'}{}^{\prime}}. \tag{6}$$

Here, $F'_{a'}$ is the average functional interest of the target user for browsing all the data. After predicting the comprehensive interest of Web big data through the infinite depth neural network, the last λ big data items can be collaboratively filtered according to the predicted value.

3. Physical Education Teaching Network Course Resource Recommendation

Collaborative filtering is also called social filtering. The user-based collaborative filtering algorithm is mainly divided into two steps:

(1) Find a collection of users with similar interests to the target user.

(2) Find items that are liked by the users in this collection and recommended to the target users that they have not heard of. The user-based collaborative filtering algorithm is only suitable for systems with few users. If there are many users, the cost of calculating the user interest similarity matrix will become very high. The increase in the space complexity and time complexity of the operation and the increase in the number of users are like the square relationship [11]. The recommendation result of this algorithm will not be updated immediately with the user's new behavior, and it is difficult to provide a convincing recommendation explanation to the user.

Based on the collaborative knowledge graph, personalized recommendations are made to network resources. In the network resources, knowledge points are distributed on different web pages. The directed acyclic graph is set as

$$G = (V, E). \tag{7}$$

Here, V represents the collection of all knowledge in the knowledge graph while E represents the collection of relationships between different knowledge points in V, which are mainly divided into two different states, connected and disconnected.

The calculation formula of individual contribution value of network resource knowledge is given as follows:

$$f(i) = \begin{cases} 1; & if\,(|\text{suc}\,(\text{i}) = 0|\text{or}\,(|\text{pre}\,(\text{i}) = |)0|) \\ \dfrac{\text{suc}\,(i)}{|\text{pre}\,(\text{i})|}, & \text{others} \end{cases}. \tag{8}$$

At this stage, the centrality calculation formula is a relatively common research method through the degree value of the node, starting from multiple solution angles, and fully reflecting the centrality between each node [12]. Related research results show that the centrality of network resources is the result of the interaction and contribution of the knowledge graph. The specific calculation method of centrality is given as follows:

$$\text{I}_\text{i} = \alpha\delta_\text{i} + \gamma\sum_{\text{j}=1}\delta_\text{j} + \cdots \gamma^\text{m}\sum_{\text{j}=\text{n}}\delta_\text{j}. \tag{9}$$

Here, I_i represents the centrality of each knowledge point; δ represents the contribution value of different knowledge points; α represents the evaluation coefficient; and γ represents the evaluation coefficient.

For different learning resources, it can be expressed as

$$I_i = \{(e_1 w_{1i}), (e_1 w_{2i}, \ldots, (e_n w_{ni}))\}. \tag{10}$$

If TF is set to represent word frequency, the calculation formula for TF is as follows:

$$\text{TF}_{ij} = \frac{n_{ij}}{\sum_k n_{kj}}. \tag{11}$$

Here, n_{ij} represents the number of times the network resource appears in the text.

Set IDF to represent the frequency of reverse documents. The main idea is the less the number of documents containing a word, the higher the ability of this word to distinguish between documents. The specific calculation formula is given as follows:

$$\mathrm{IDF_i} = \log \frac{|D|}{\left|j\colon e_i \in d_j\right| + 1}. \quad (12)$$

Here, $|D|$ represents the total number of documents in network resources and $|j\colon e_i \in d_j|$ represents the number of documents contained in the word and adding 1 to the denominator is mainly to prevent the occurrence of 0 [13].

To improve the data processing speed of the entire algorithm, all experimental data need to be initialized and normalized. The following specific calculation formulas are given:

$$v = \mathrm{uniform}\left(-\frac{6}{\sqrt{d}}, -\frac{6}{\sqrt{d}}\right). \quad (13)$$

At the same time, the entity and relationship vectors are normalized and the following calculation formula can be obtained:

$$v' = \frac{v}{\|v\|}. \quad (14)$$

Based on the above analysis, the quantitative representation method of the items in the knowledge graph and the collaborative filtering algorithm are combined, and the semantic information of the network resources is extracted from the collaborative knowledge graph to achieve the personalized recommendation of the network resources [14].

Since the newly registered user in the course selection system has no record of course selection, they cannot directly use the collaborative filtering algorithm to find similar neighbors to recommend personalized course selection for them. Here, we adopt the nearest neighbor recommendation based on the attribute value preference matrix. The major two prerequisites' steps are as follows:

(1) The user has filled in basic information, such as name, student ID, and major, and the learning style measurement scale when registering.

(2) The system automatically generates a student model based on the user's registration information and learning style and converts the model into a vector space model. With this premise, the algorithm flow of the recommendation engine is as follows:

$$P(u, j[k]) = \frac{\sum_{h-1}^{H} R_h(u, Gj([k]))}{H}. \quad (15)$$

$$\mathrm{APM} = \begin{bmatrix} P(u,1[1]) & P(u,2[1]) & \cdots & P(u,t[1]) \\ P(u,1[2]) & P(u,2[2]) & \cdots & P(u,t[2]) \\ . & . & \cdots & . \\ P(u,1[i]) & P(u,2[i]) & \cdots & P(u,t[i]) \end{bmatrix}. \quad (16)$$

$$sim(u, v) = \frac{\|A_{u,v}\|}{1 + \sum_{i=1}^{\|A_{u,v}\|} \sqrt{|R_{u,i} - R_{v,i}|}}. \quad (17)$$

(1) According to the student model and the course selection record database, generate a student-course selection matrix of order $R(m \times n)$ for each student in the student space (if the student has taken the course, then the score of the course is set to 1; otherwise it is 0).

(2) Use the cosine similarity formula (14) to calculate the similarity between the target learner u and any learner v in the student space. By calculating the similarity, the first several learners with the largest similarity are taken as the initial neighbor set $IniSet(u)$ of the standard learner u. Determine the size of $IniSet(u)$ according to the number of learners in the student space and the corresponding ratio. At the same time, it is necessary to ensure $k \ll n$, which can reduce the time complexity of the algorithm, thereby improving the real-time performance of the algorithm.

(3) Generate a new student-course selection matrix R' based on the initial neighbor set of the target learner and the target learner u generated in the second step.

(4) According to the course selection record database, map the courses taken by the target learner from the course information table to the course attribute value table [15]. Because different courses have different attributes, each attribute has a different score for each course, so we should first count the score set $G(j[k])$ of each attribute value. $G(j[k])$ represents the k-th value of the course attribute j (the number of courses determines the value of k), and $P(u, j[k])$ is used to represent the learner u's interest preference for the attribute value $G(j[k])$, as shown in the following formula:

Here, $R_h(u, G(j[k]))$ represents the score of the learner u on the course attribute, and H refers to the total number of times the learner u has scored the value $G(j[k])$ of the attribute j. Using the learner's interest preference $P(u, j[k])$, the learner u's preference matrix APM for course attribute values can be obtained, as shown in the following formula:

The attributes of the courses in the course selection system will be automatically converted into the corresponding course model after uploading the course, and the course attributes will be stored in the course database. The course information table is shown in Table 1.

(5) Based on the attribute value preference matrix APM generated in the fourth step, the similarity formula is used to calculate the similarity between the target learner u and other students in the student space. The similarity formula is as follows:

Table 1: Course information table.

	Attri (1)	Attri (2)	C_1	Attri (j)	C1	Attri (i)
C_1	$G_{1,1}$	$G_{1,2}$	$\cdots$	$G_{1,j}$	$\cdots$	$G_{1,t}$
C_2	$G_{2,1}$	$G_{2,2}$	$\cdots$	$G_{2,j}$	$\cdots$	$G_{2,t}$
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
C_i	$G_{i,1}$	$G_{2,1}$	$\cdots$	$G_{i,j}$	$\cdots$	$G_{i,t}$

Here, $\|A_{u,v}\|$ represents the size of the collective score attribute value set of learner u and learner v; learner u's score for the i-th attribute is expressed as $R_{u,i}$; and the value should be less than $\|A_{u,v}\|$.

(6) Sort the similarity between the target learner and other learners in descending order. Intercept the first k learners with the largest similarity as the nearest neighbors of the target learner; store them in the nearest neighbor set $U\,(U = \{u_1, u_2, \ldots, u_k\})$ of the target learner, and the U set does not contain u.

(7) Find out which courses they have taken from the set U of the nearest neighbors of the target learners and store them in the set IU. Then, delete the courses that the target learner has taken from the set IU, and the remaining courses can be used as the recommended set of elective courses for the target learner C_{can}.

(8) Suppose the number of items in C_{can} is Q, and the number of recommended courses is T; then, when $Q \leq T$, C_{can} is directly used as the recommended set C_{rec}; when $Q > T$, first use the prediction formula (17) to calculate the target learner's prediction value for the courses in the recommendation set C_{can}. Then, the predicted value is sorted in descending order, and the top T courses with the highest predicted value are selected as the final recommended course set C_{rec} for the target learner.

4. Experimental Study

4.1. Results and Analysis of Data Experiments on the Resources of the Network Courses of Physical Education. A data set of physical education online course resources on a certain platform is used here, and users with less than 20 clicks are deleted based on the data set to form 1,486 users' browsing information on 1,430 pages. Randomly extract 1,250 records from this data set and divide them into 1000 training sets and 50 test sets (divided into 5 groups of current users). To test the prediction quality under different amounts of information, each group of visible user interests is randomly selected. The number of visible interest pages of the user is from 5 to 20 pages, named Given5 ~ Given20, respectively. The sparsity level ψ_{gl} of this data set is as follows:

$$\psi_{gl} = 1 - 50561/1250 \times 1430 = 0.9717. \tag{18}$$

It can be observed that this data set is sparser than the MovienLens data set ($\psi_{ml} = 0.9369$) and belongs to the severe sparse level. The test environment and system's characteristics are shown in Table 2.

4.2. Evaluation Index. To further evaluate the effect and accuracy of the recommendation, the recommendation system can also use three commonly used evaluation indicators in the field of information retrieval as the standard to measure the recommendation effect, namely, Precision, Recall and F1 value. The data set is divided into a training set and a test set. The model of the recommendation algorithm is learned and parameter adjusted on the training set; then, the recommendation result is calculated on the test set to obtain the evaluation result:

(1) Precision: the proportion of recommended pages (hit) that are correctly identified in the Top-N recommendation set:

$$\text{precision} = \frac{|\text{test} \cap \text{TopN}|}{\text{N}}. \tag{19}$$

(2) Recall rate (recall): the proportion of recommended pages (hit) that are correctly identified in all test sets:

$$\text{recall} = \frac{|\text{test} \cap \text{TopN}|}{|\text{test}|}. \tag{20}$$

(3) F_1-measure: an indicator that integrates the above two evaluation indicators. Considering that the accuracy and recall rates of different systems are mutually high and low in some cases, it is impossible to make a judgment using only the above two indicators. Therefore, the F_1 value is introduced, and these two indicators can be used at the same time to fully explain the performance of the algorithm. The calculation formula of F_1 is as follows:

$$F_1 = \frac{2 \times (\text{precision} \times \text{recall})}{\text{precision} + \text{recall}}. \tag{21}$$

4.3. Experimental Results and Discussion. According to the steps of the new algorithm, the training model m is first smoothed, the pages with no interest value are preliminarily predicted through the item-based collaborative filtering algorithm, and the filled training model m' is obtained. After the principal component analysis of m', its cumulative contribution rate is shown in Figure 1. The solid line part in Figure 1 represents the cumulative contribution rate of each principal component of the smoothed model m'. The first 58 and the first 147 principal components with a cumulative contribution rate of 80% and 90% are selected as the dimensions of the transformed vector, respectively. Clustering is performed in a low-dimensional space. Table 3 describes the naming of the contrast algorithm used in this experiment:

$$\text{MAE} = \frac{\sum_{i=1}^{n} \left| P_i - R_i \right|}{N}. \tag{22}$$

Note that the MAE metric, as given by formula (22), represents the average absolute error value index, where P_i represents the data predicted value obtained through the

Table 2: Test environment and system's characteristics.

Processor	Intel(R) Core (TM) i5-3210M CPU @ 250 Hz 250 Hz
Memory capacity	4.00 GB
Operating system	Windows 7 Home Basic 64 bits
Hard drive capacity	5400 rpm
Graphics card	NVIDIA GeForce GT 630M + Intel GMA HD 4000

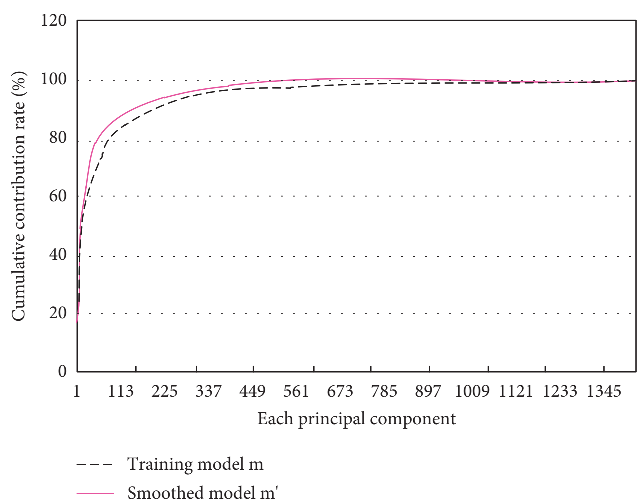

Figure 1: The curve comparison of the cumulative contribution rate of the principal components of m and m' in the log data set.

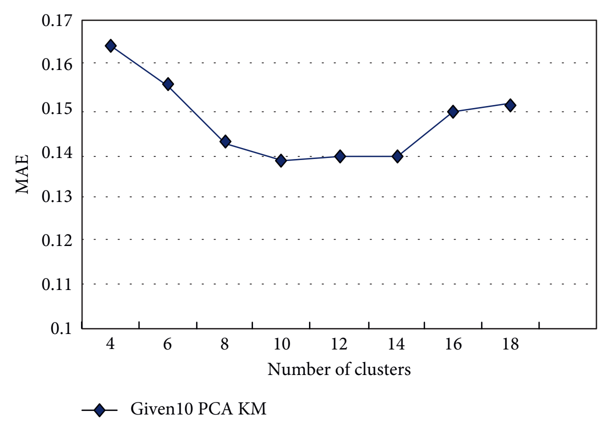

Figure 2: The impact of different cluster numbers on recommendation accuracy.

Table 3: Name description of each algorithm.

Algorithm naming	Algorithm description
UPCC	User-based CF
KCLUST-CF	K-means clustering
PCA90-UPCC	PCA + UPCC
PCA-KM90	PCA + K-means clustering
PCA-SOM90	PCA + SOM clustering

algorithm, R_i represents the true value obtained from the real data, and N represents the number of samples in the predicted data.

Figure 2 records the influence of the number of clusters on the MAE under the experimental conditions of Given10. It is preliminarily judged that the optimal number of clusters k should be between 8 and 12. We might set $k = 9$ in future experiments.

To improve the accuracy of the two-stage prediction algorithm proposed in this paper, we designed two sets of experiments. The first set of experiments used different clustering algorithms (K-means clustering and collaborative filtering technology methods) to compare the prediction accuracy. It also compares the classic collaborative filtering algorithm UPCC (user-based collaborative filtering), and the collaborative filtering algorithm based on user clustering. The second set of experiments compared the effect of taking 90% and 80% of the cumulative contribution rate of principal components on the quality of prediction. In the experiment, K-means clustering uses Cosine distance measurement, and the output of the collaborative filtering technique method is a 3×3 two-dimensional neuron node, the training step is 1000, and the learning rate is an exponential decay function.

The experimental results of Figure 3 show that the overall quality of prediction of the algorithm gets more accurate with an increase in the amount of information about historical interest. For extreme sparse matrices, it can be observed that collaborative filtering is more feasible for clustering within the transformed low-dimensional spaces. Moreover, compared with the collaborative filtering algorithm, which is based on user clustering (KCLUST_CF), the traditional UPCC nearest neighbor algorithm still has much better prediction accuracy.

Table 4 summarizes the offline and online computing time complexity of several comparison algorithms. It can be observed that the new algorithm based on effective dimensionality reduction and clustering proposed in this paper has a better real-time recommendation effect.

Several sets of comparative experiments will be conducted on the accuracy of the algorithm to generate recommendations. First, hide m page preferences for each user in the test set. The rest is used as historical preference information to predict the interest value of unknown pages, and on this basis, N pages with the highest predicted interest value are selected and recommended to the user. If the recommended page appears on a previously hidden page, it is called a hit. In this experiment, $m = 10$ and $N = 5$, that is, the recommendation model selects the first 5 pages with the highest predicted interest value as the recommendation output to the user. It can be seen from the comparison curve, in Figure 4, that, as the number of N increases, the accuracy of the recommendation will continue to decline, and finally

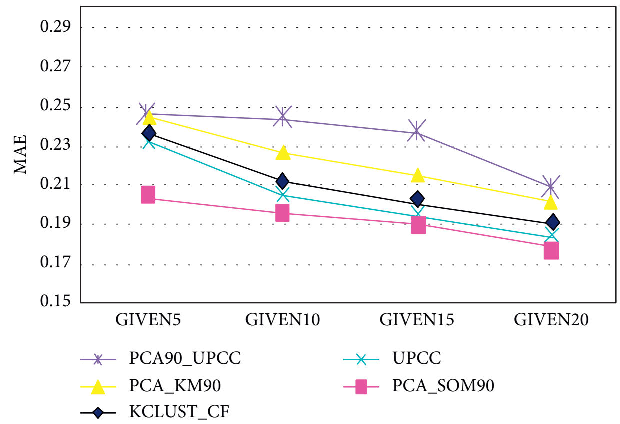

FIGURE 3: Comparison of prediction accuracy of different algorithms.

TABLE 4: Comparison of time complexity of improved collaborative algorithms.

Algorithm	Offline time complexity	Online time complexity
UPCC	—	$o(mn)$
KCLUST_CF	$o(mtk)$	$o(n)$
PCA90_UPCC	$o(n^2m) + o(n^3)$	$o(m\ d)$
PCA90_KM	$o(n^2m) + o(n^3) + o(mtk)$	$o(d)$
PCA90_SOM	$o(n^2m) + o(n^3) + o(t^2d)$	$o(d)$

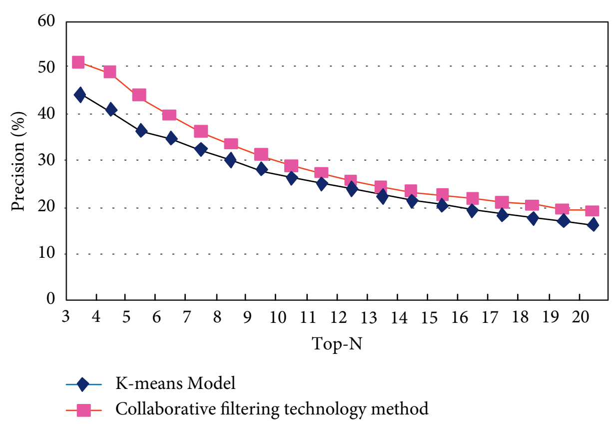

FIGURE 4: Comparison of recommended accuracy rates.

TABLE 5: Comparison of evaluation indicators of the two models.

Metrics	PCA_K-means model	Collaborative filtering technology method
Mean precision (%)	36.4	43.6
Mean recall (%)	15.19	15.40
Mean F1	0.2144	0.2277

gradually stabilize. In general, the recommendation performance of the collaborative filtering technology method is better than that of the K-means model. As shown in Table 5, the average recommendation satisfaction degree of the collaborative filtering technology method is approximately 43.6%, while the evaluation recommendation satisfaction degree of the K-means model is somehow 36.4%, which is far less than that of the former method. Therefore, compared with the accuracy rate, the recall rates of the two models are relatively low. The reason that we believe is that the N value and the size of the test set affect the recall rate.

Table 6 reflects the comparison of the statistical prediction accuracy of the two models, as well as the prediction of the degree of interest of the portal page. The prediction accuracy of the collaborative filtering technology method is more accurate than that of the K-means model. This finding

Table 6: Comparison of the recommended quality of the two models (MAE values).

Model	Given5	Given10	Given15	Given20
PCA_K-means	0.24565	0.22685	0.2158	0.2023
Collaborative filtering technology method	0.2045	0.19705	0.1903	0.1787

was observed since the average MAE of the proposed method is reduced by approximately 0.03. Particularly, when there is less predictive historical information (e.g., Given5), the collaborative filtering technology method performs better in predicting quality, and the MAE is reduced by 0.041. Table 6 shows that the larger the historical importation, the lesser the MAE value.

In short, the page recommendation experiment in this data set illustrates that the recommendation method based on collaborative filtering technology shows better prediction accuracy and improves the accuracy of the recommendation. Moreover, the time complexity of the online model is significantly reduced, which is a sign of a more practical online recommendation model.

5. Conclusions and Future Work

The fulfillment of individualized educational resource recommendations has become the key problem that has to be solved in intelligent education due to the dual pressures of work and study. Since the personalized recommendation system has become the focus of current research on how to integrate with online teaching as a critical technology to alleviate the problem of cognitive overload or confusion during online learning, student's interests are not static and the recommended results should be updated continuously with the changes of students' interests, which helps to cultivate the potential interests of users. Therefore, the requirements for the system to respond immediately to changes in user interest are very high. To solve the real-time problem of the recommendation system, many scholars have proposed a model-based collaborative filtering algorithm based on user clustering, which has achieved certain results.

Based on the collaborative knowledge graph, this paper combines the collaborative filtering algorithm to extract the semantic information of teaching network resources from the collaborative knowledge graph. According to the nearest neighbor recommendation principle, the course attribute value preference matrix APM is obtained, the course predicted values are sorted in descending order, and the top T courses with the highest predicted value are selected as the final recommended course set for target learners. Finally, the rehearsal platform was put through its paces in terms of functionality and performance, yielding the expected results. The rehearsal platform provides students with appropriate IT learning resources as well as a platform for learning exercises, and the recommendation system not only helps users locate high-quality content that interests them fast but also saves them time and money. The search range of the nearest neighbor is narrowed, the feature information is more concentrated, and a better recommendation effect is obtained in the test on the standard data set and the real data.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Article

Application of Fuzzy Comprehensive Evaluation Based on Genetic Algorithm in Psychological Measurement

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Fuzzy comprehensive evaluation (FCE) is an artificial evaluation technique based on fuzzy mathematics, with real and accurate evaluation results that are extensively utilized in psychology and other fields. Hence, a technique is needed for assessing Likert scale data using fuzzy mathematics. This study examines the operators and weight distribution of the variables while individuals perform a complete and comprehensive evaluation and apply a genetic algorithm (GA) to determine the corresponding weight. Genetic processes based on population adaptation and evolution fundamentals have been hugely successful in solving problems and producing optimal solutions a long time ago. Furthermore, we measure psychological data from the Likert scale and analyze it using a fluid-based GA for a complete psychological assessment. Students of various genders used different compound operators and weight distribution to evaluate the instant noodle completely. This reflects the fact that the employment of a GA-based fuzzy comprehensive evaluation in psychological measurement and consumer psychology study is beneficial. The results show that the fuzzy comprehensive evaluation method based on the GA can effectively analyze the psychological measurement data of the Likert scale.

1. Introduction

The Likert scale is one of the most commonly used measurement tools in psychology [1]. When people analyze the data from the scale, they usually use the method of mathematical statistics. In other words, they think that the uncertainty of these data comes from randomness. However, there are many differences between psychological measurement and physical measurement. Because psychological measuring data is derived from the respondents' subjective reactions, particularly data acquired using the Likert scale, its uncertainty is higher [2]. Fuzziness and randomness are not the same. The uncertainty caused by randomness is due to the insufficient grasp of the causal relationship of things; that is, the conditions of things cannot be strictly controlled so that some accidental factors make the experimental results uncertain, but things themselves have obvious meanings [3]. The subjects' answers to intelligence test questions, for example, are frequently influenced by random factors and reflect a degree of uncertainty. It is appropriate to use the method of mathematical statistics to deal with these data. Fuzziness means that the limit of some things or concepts is not clear, which reflects the transition state between different concepts [4]. For example, the concepts of "comparative agreement" and "very agreement" in the Likert scale are fuzzy. Unfortunately, this fuzziness has not been properly studied in the current psychological measurement. People usually record these fuzzy concepts of the Likert scale as 1 to 5 points directly and then use the method of mathematical statistics to deal with it. This is not appropriate, because the uncertainty of the data obtained by the Likert scale is mainly reflected in the fuzziness, so whether the method of fuzzy mathematics can analyze this kind of psychological measurement data is a problem that needs to be discussed. The Likert scale is often used to score multiple variables in some areas of psychological measurement. Variables such as morality, ability, diligence, and performance, for example, are scored in personnel evaluation; in consumer psychology, the appearance, function, price, after-sales service, and other variables of the goods are scored. Multiple regression equations are often used in psychological statistics to describe the relationship between Likert scale scores obtained from multiple variables.

In fuzzy mathematics, the fuzzy relation equation reflects the results of fuzzy comprehensive evaluation [5]. In fuzzy comprehensive evaluation, the scores of multiple independent variables are transformed by some operator to get the scores of dependent variables, which is very similar to multiple regression equations. However, in the framework of fuzzy mathematics, the scores of independent variables are usually called single-factor evaluation, and the scores of dependent variables are called comment set scores. In fuzzy comprehensive evaluation, the main problem is the operator used, and there are four different operators [6]. People use the "maximum and minimum" operator or the "main factor determining" operator in the comprehensive evaluation, according to fuzzy mathematicians [7–10], but the hypothesis has yet to be validated in psychology. In the fuzzy comprehensive evaluation, it is also important to examine the kind of operator used.

A fuzzy comprehensive evaluation is a process of integrating multiple independent variable scores into a dependent variable score. The traditional method is to determine the weight by expert scoring, which is subjective. We use other objective methods to obtain the weight distribution. In the use of multiple regression equations, the least square method is usually used to determine the coefficients of each independent variable. These coefficients reflect the weight of each independent variable. It is an optimization problem to find the most suitable weight for the comprehensive evaluation of the subjects. A genetic algorithm (GA) simulates the evolution process of organisms and is a new global optimization method. It is used to figure out how much a fuzzy comprehensive examination is worth.

Not only should research be academically valuable, but it should also have a practical application. With the deepening impact of the current financial crisis on the real economy, the government has put forward some policies to expand domestic demand. If enterprises do not understand the needs of consumers, this is equivalent to selling products with their eyes closed. Therefore, it is very important to understand consumers' purchasing psychology and the weight of the impact of various attributes of goods on consumers.

According to the principle of market segmentation, enterprises should understand the different preferences of different target consumer groups for commodity attributes [11]. To find out whether they use the same operator in the fuzzy comprehensive evaluation, it is necessary to analyze the operator and weight distribution used by different subjects in the fuzzy comprehensive evaluation of goods. Based on the theoretical problems and practical requirements of psychological measurement described above, this study attempts to combine the genetic algorithm with a fuzzy comprehensive evaluation method by using the data from college students' evaluations of Master Kang's braised beef noodles as an example. Analysis of Likert data and customer preferences for various product features and operators was used in a complete fumigated assessment. The following are the main contributions of the proposed study:

(i) Firstly, we investigated related work in the field of psychological measurement and concluded that the best performance is achieved during psychological measurement.

(ii) Secondly, we chose the most accurate classification method, such as the genetic algorithm, as well as frequently used psychological assessment instruments, such as the Likert scale.

(iii) Thirdly, Likert scale variables have been widely used to determine actual data, from a huge quantity of college data of male and female students to weight distribution of each independent variable of psychological measurement via fuzzy evaluation.

(iv) Finally, the fuzzy relation equation reflects the results of a fuzzy comprehensive evaluation using Likert scale tools and a genetic algorithm to predict psychological measurement using fuzzy mathematics.

The remainder of the paper is organized as follows: Section 2 presents related research work; Section 3 depicts fuzzy comprehensive evaluation and genetic algorithm; Section 4 depicts empirical research, research objective, collected source code, research results, and experimental examination; and Section 5 discusses the operator in the fuzzy comprehensive evaluation method and application of the genetic algorithm. In the final section (i.e., Section 6), we conclude our paper.

2. Related Work

Psychological measurements, often known as psychological tests, are standardized assessments of a psychological characteristic like personality, intellect, or emotional functioning. They frequently comprise a sequence of true or false questions that respondents must answer. One of the most often used devices for assessing psychological exams is the Likert scale. Likert [12] proposed the scale, which comprises a set of questions that serve as markers of psychological measures. The scores in question, according to the author of [13], are built on an interval scale since they are obtained by psychological scaling. The psychological factors are assessed by the combined values of all interval questions [14]. Nevertheless, many scientists claimed that, in Likert, only facts structured in an ordinary scale are of course the option or the response. Regarding Likert, the interval variety of different levels has been claimed [15] to be not equal. The Likert scale thus is organized in an ordinal way. Analyzing data with added, subtracted, divided, or replicated data is improper. In addition, the analysis utilizing the arithmetical mean and the standard deviation [16] of such data is incorrect. As a result, assessing psychological variables by combining all items on the Likert scale is not appropriate. Furthermore, the authors in [17] noted that, in general, researchers would aggregate the scores from each item and then use the total scores to assess the variables, which is wrong because each item's weight is uneven.

Due to the difficulties described above, several attempts have been made to address this issue and develop an acceptable scale. Fuzzy logic is one of the approaches. It was created by [18] from a hazy set. The authors of [19] improved the Likert scale using fuzzy logic, resulting in a novel scale recognized as the fuzzy Likert scale. In this regard, the author in [20] linked the effectiveness of this scale to the Likert scale and discovered that measuring the variables using the fuzzy Likert scale was more precise than evaluating them using the conventional Likert scale.

By integrating the analytic hierarchical process (AHP) with the fuzzy evaluation technique, the authors of [21] presented a universal approach to usability evaluation. This technique develops a hierarchical index based on three major accessible qualities, product performance, efficiency, and customer satisfaction, by combining numerous sources of ambiguous information throughout product usability assessment.

Planning technology combines many fuzzy information sources to analyze in the process of product usability evaluation. The technology includes indicators such as accessible quality, product performance, efficiency, and customer satisfaction.

3. Fuzzy Comprehensive Evaluation and Genetic Algorithm

In this section, we explain fuzzy comprehensive evaluation and generic algorithms in detail.

3.1. Fuzzy Comprehensive Evaluation

3.1. Fuzzy Comprehensive Evaluation. The fuzzy comprehensive evaluation technique [15] is a mathematical approach for thoroughly evaluating things that are difficult to specify in the actual world utilizing fuzzy mathematics thinking and methodologies. Fuzzy mathematics has seen fast theoretical progress and widespread application for more than 30 years. The fuzzy comprehensive evaluation technique employs fuzzy mathematics' fuzzy set theory to completely evaluate systems. Information on the priority of various alternatives may be obtained as a guide for decision-makers to make decisions using fuzzy evaluation. We need to first construct a fuzzy comprehensive evaluation index system while using the fuzzy comprehensive evaluation approach. The following essential ideas should guide the development of a fuzzy comprehensive assessment index system:

(i) There should be a comprehensive assessment index system
(ii) The evaluation index must be quantifiable and comparable in the evaluation index system
(iii) It is important to highlight the human aspect in the evaluation index and to completely integrate human variables for assessment in education
(iv) The assessment level in the assessment index should not be too thinly split

3.1.1. Fuzzy Set. There are many vague concepts in the objective world, such as "comparative agreement" and "very agreement" in the Likert scale. To express the fuzzy concept mathematically, American cybernetics expert Professor Zadeh put forward the concept of fuzzy set in 1965 and created a new discipline of fuzzy mathematics. The relationship between element x and fuzzy set A breaches the membership degree limitation in fuzzy mathematics. In general set theory, this can only take 0 and 1, but it may be extended to any value in the interval [0.1]. The membership function of A expresses the membership of element x in the fuzzy set A.

The identification of the membership of a given problem is a major step towards resolving practical difficulties utilizing fuzzy mathematics. Five-point, three-point, fuzzy distribution, and fuzzy statistics approaches are among the ones proposed by experts both at home and abroad. In this study, a fuzzy statistical method will be used to get the membership function.

3.1.2. Elements of a Fuzzy Comprehensive Evaluation. A fuzzy comprehensive evaluation is to take fuzzy mathematics as a tool to make a comprehensive evaluation of something under the condition of considering a variety of factors. The evaluation model includes three elements [22]:

(1) Factor set $U = \{u_1, u_2, \ldots, u_m\}$
(2) Comments collection $V = \{v_1, v_2, \ldots, v_n\}$
(3) Single-factor judgment $f(u_i) = \{r_{i1}, r_{i2}, \ldots, r_{in}\}$, r_{ij} form fuzzy matrix R。

In this study, the subjects made a comprehensive evaluation of Kang Shi Fu's braised beef noodles. Taste, appearance packaging, cake size, price, seasoning package, and advertising are among seven factors in the factor set. The comment set included five comments:

(i) Very dissatisfied
(ii) Relatively dissatisfied
(iii) Average
(iv) Relatively satisfied
(v) Very satisfied

Single-factor judgment is the evaluation of the seven factors mentioned above.

3.1.3. The Model of a Fuzzy Comprehensive Evaluation. The goal of the fuzzy evaluation model is to create a fuzzy mapping between each assessment component, such as effectiveness, competence, and user happiness, and a set of definite assessment scores, such as good or outstanding. The aim is to construct fuzzy sets for the assessment elements; for example, a given usability score, say 5 on a 7-point scale, may be assigned to both the outstanding scores. However, based on the weights assigned to each assessment component and the average scores given by various raters, the amount of each grade that the usefulness score corresponds to may differ. Figure 1 depicts the formal methods of our proposed fuzzy evaluation model.

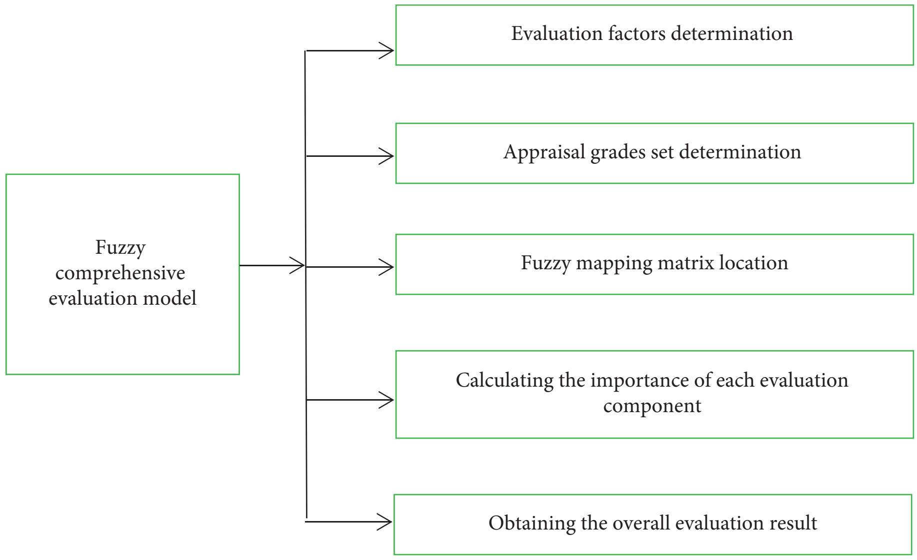

Figure 1: The fuzzy comprehensive assessment model's steps.

Step 1. Evaluation factors determination: the evaluation object, factor set, and comment set are all determined in the first phase. In this study, the evaluation object is Master Kang's braised beef noodles, and the factor set and remark set are described in the preceding section.

Step 2. Appraisal grades set determination: $V = v1, v2, \ldots, vm$, where m is the number of levels in the appraisal, representing the appraisal set as a vector. For instance, if $m = 5$, the assessment vector V = extremely poor, poor, medium, good, excellent might be expressed. In the second stage, expert consultation methods and analytic hierarchy procedures are used to create the weight distribution vector A of assessment factors. This weight distribution component is a tough topic, and experts frequently struggle to describe the weight in their brains with numbers; therefore, in this work, we attempt to estimate the weight vector using a genetic algorithm.

Step 3. Fuzzy mapping matrix location: the fuzzy comprehensive evaluation matrix R is obtained in the third phase by evaluating each component.

Step 4. Calculating the importance of each evaluation component: the relative relevance of each assessment element in the overall product rating should be measured to get a thorough usability assessment. W, which can be constructed via the AHP technique, can represent the weight vector. As previously mentioned, weight may be expressed for n evaluation factors by the vector $W = (W1, W2, \ldots, Wn)$, which is equal to the sum of every element 1. A composite method such as this is utilized during the fourth stage to obtain the comprehensive evaluation results B.

This is called the fuzzy relation equation, and it was developed by mathematicians who proposed four different operators, resulting in the four models that will be described later. The full assessment findings of Kang Shi Fu's braised beef noodles were collected directly using the Likert scale in this study. The task at hand is to solve the value of a from the fuzzy relation equation i.e., invert the fuzzy comprehensive evaluation, to obtain the weight vector.

Step 5. Obtaining the overall evaluation result: The total assessment outcome may be determined by considering the comparative weights of every evaluation component so that a single vector representing a similar level of assessment scores m can be expressed as

$$B = (b1, b2, b3 \ldots bm) = W * R, \tag{1}$$

where "*" is an arrangement operator.

The various processes in the composition impact how different weight distributions, i.e., in vector W, modify the final evaluation vector B. There is obvious overriding importance in the choice of the composition operators. We presume, for the current purpose, that all assessment variables have to be taken into account, such that there is no one aspect more picked or disregarded than others. We thus opt to utilize the operator composition which determines each member Bj of the last evaluation vector using the following formula which is suited for assessments that must accommodate every weight of the factors:

$$Bj = \min\left\{1, \sum_{i-1}^{n} Wirij\right\} (\text{where } I, \quad j = 1, 2, 3 \ldots, n). \tag{2}$$

Rendering to the different composition operators, the following four models are obtained [6–10]:

(i) The main factor is decisive, and its operator is

$$M(\Lambda, V),$$
$$b_k = \Lambda_{k=1}^{m}\left(a_k \Lambda r_{kj}\right) = \max\left\{\min a_k, r_{kj}\right\}. \tag{3}$$

The operator only considers the most important factor; other factors do not really work.

(ii) The main factor is type I, whose operator is

$$M(\cdot,V),$$
$$b_k = \Lambda_{k=1}^{m}\left(a_k \Lambda r_{kj}\right) = \max\left\{\min a_k, r_{kj}\right\}. \tag{4}$$

The model is a little more accurate than the main factor determinant because it uses ordinary multiplication and considers all factors.

(iii) The main factor highlights type II, whose operator is $M(\wedge,\oplus)$, where $\oplus$ is a bounded sum, that is

$$S_1^{\oplus}, S_1^{\oplus}, \ldots, S_1^{\oplus} = \min\left(1, \sum_{k=1}^{t} S_k\right). \tag{5}$$

Since the sum of the weights is equal to 1,

$$b_j = \oplus_{k-1}^{m}\left(a_k \Lambda r_{kj}\right) = \sum_{k=1}^{m}\left(a_k \Lambda r_{kj}\right). \tag{6}$$

The model uses the method of summation, and the result is more accurate than that of the main factor determinant.

(iv) Weighted average type, whose operator is

$$M(\cdot,+), b_j = \sum_{k=1}^{m}\left(a_k \Lambda r_{kj}\right). \tag{7}$$

Theoretically, this model is more accurate than the above three models.

Even though mathematicians have proposed operators for these four types of composition operations, they have neglected to describe the types of operators and models that people employ in the comprehensive evaluation. There has not been an empirical study of psychology to assess it yet; therefore it is an issue that has to be addressed.

3.2. Genetic Algorithm. Although mathematicians proposed operators for these four combinatorial operations, they ignored the types of operators and models used by humans in their thorough review. There has not been any empirical psychological research to assess this, therefore it is a problem that has to be addressed. The genetic algorithm imitates the concept of biological evolution by applying genetic operators such as selection, crossover, and mutation to a population to generate a new generation of the population while seeking the best answer.

3.2.1. Elements of Genetic Algorithm. Imitating the diversity of biological evolution, people put forward a variety of coding methods and genetic operators of genetic algorithms. Goldberg summarized them as a unified genetic algorithm, called simple genetic algorithm (SGA) [23].

(i) Chromosome coding method

(ii) Individual fitness evaluation

(iii) Genetic operators, including selection, crossover, and mutation

(iv) Operation parameters including population size m, terminal evolution algebra T, crossover probability P_ c∘, and variation probability p_ m∘

The basic genetic algorithm can be defined as an 8-tuple as in (12).

$$SGA = (C, E, P_0, M, \Phi, \Gamma, \Psi, T), \tag{8}$$

where C is the individual coding mode, E is the individual fitness evaluation function, P_0 is the initial population, M is the population size, selection operator, Γ is the crossover operator, Ψ is the mutation operator, and T is the termination condition.

3.2.2. Implementation of Genetic Algorithm

(1) Coding Method. The method of transforming the feasible solution of a problem from its solution space to the search space that a genetic algorithm can handle is called coding, which is the primary problem when using the genetic algorithm to solve practical problems. The commonly coding methods include binary coding method, gray coding method, floating-point coding method, and symbol coding method. The binary coding method uses the symbol string composed of 0 and 1 to represent the individual. Gray code is a coding method in which only one code bit is different and the other code bits are identical between the coding values of two consecutive integers. In the floating-point coding method, each gene value of an individual is represented by a floating-point number in a certain range. That is, the true value of the variable is used to encode the data. Symbol coding means that gene values are taken from a symbol set with no numerical meaning but only code meaning.

People usually use different coding methods according to the nature of the problem to be solved. The floating-point code method is used in this study as it can represent a large range, provides the best precision solution, is efficient, and makes it easy to perform a genetic search in a large space. Let the optimization be the minimization problem by (13):

$$\left\{\begin{matrix} \min f(x), \\ L(j) \le x(j) \le U(j), \end{matrix}\right\} \tag{9}$$

where $x = \{x(j)\}$ is the optimization variable set.

$[L(j), U(j)]$ is the change interval of $x(j)$, and f in the objective function.

In floating-point coding, (14) is used as linear transformation.

$$x(j) = L(j) + y(j)[U(j) - L(j)]. \tag{10}$$

The j^{th} variable $x(j)$ with initial change interval $[L(j), U(j)]$ is transformed into floating-point number $y(j)$ on [0, 1] interval, so that the value range of all variables is unified to [0, 1] interval.

(2) Fitness Function. In a genetic algorithm, fitness is used to measure the degree to which an individual is helpful to find the optimal solution in optimization calculation. The function that measures individual fitness is called fitness function. The evolutionary process of a group is based on the fitness of each individual in the group. Through repeated iterations, the individual with the best fitness is constantly sought until the optimal solution or approximate optimal solution of the problem is obtained. To prevent premature phenomena and maintain the diversity of the population, it is necessary to expand or reduce the fitness of individuals in different stages of the genetic algorithm, which is called fitness scale transformation. The commonly used transformation methods are linear scale transformation, power scale transformation, exponential scale transformation, and ranking scale transformation. The ranking scale transformation is used in this study, which is based on everyone's fitness order rather than the score value. The most suitable individual number is 1, followed by 2 and so on. The advantage of this transformation is that the scale value of the individual is proportional to the size of the population n, and the sum of the scale values of the whole population is equal to the number of parents of the next generation, which avoids the influence of the initial value limit [23].

(3) Selection Operator. In the process of biological heredity, the species with higher adaptability to the environment will have more chances to survive to the next generation. The selection operator is used in the genetic algorithm of survival of the fittest to carry out the operation of "survival of the fittest." The common selection operators are roulette, optimal saving strategy, deterministic sampling selection, and random selection without playback. In this study, we used the division ratio of the faceplate for segmentation. The probability of everyone being selected is directly proportional to their fitness.

(4) Crossover Operator. Crossover operator refers to the crossover operator used by two chromosome pairs in a certain way, including single-point crossover, two-point crossover, multipoint crossover, uniform crossover, and arithmetic crossover. In this study, we use a two-point crossover, that is, randomly set two crossover points in the coding string of two paired individuals and then exchange the chromosomes between the two crossover points.

(5) Mutation Operator. The mutation operator is used to replace the gene values of some loci in chromosome coding string with other alleles to form a new individual. The commonly used mutation operators are basic bit mutation, uniform mutation, boundary mutation, nonuniform mutation, and Gaussian mutation. In this study, Gaussian mutation is used to replace the original gene value with a random number under the standard normal distribution, which is more suitable for floating-point coding.

3.3. Fuzzy Comprehensive Evaluation Based on Genetic Algorithm. Compared with computers, people can often deal with fuzzy information better. One of the original purposes of establishing fuzzy mathematics is to use mathematical methods to describe people's fuzzy information processing process. A fuzzy comprehensive evaluation describes how people arrived at an overall evaluation of something by evaluating individual factors. Because it is difficult for people to accurately articulate the weight distribution in their heads, knowing how much each element costs is one of the keys. As a result, evaluating the weight value of each factor in a fuzzy comprehensive evaluation is very difficult. When the researchers cannot let the subjects express the weight distribution in their minds by the oral report method commonly used in psychology, they get the weight from other ways. The excellent optimization function of the genetic algorithm provides a good inspiration. The process of searching for weights is to search a group of values so that the results obtained by substituting them into the fuzzy relation equation are the most consistent with the actual response of the subjects. This is a process of searching for the optimal solution. Therefore, this study uses a genetic algorithm to search for a group of values that can represent the weight distribution in the brain of the subjects and uses the actual response values of the subjects for testing; the results are more reliable than those of the oral report method.

4. Experimental Work and Simulation Results

4.1. Experimental Work. In this portion of the study, we provide the experiments that were carried out as well as the simulation findings obtained during these studies. Many simulation experiments on the suggested psychological measurement were conducted utilizing fuzzy comprehensive evaluation based on the evolutionary algorithm. During our experimental work, we acquired the weight and fitness of male and female students' evaluations of various criteria under different operator models using the genetic algorithm, and we classified the weights of males and females into two categories: normalized weights and ranking weights. Table 1 shows the hardware requirements for the experimental work.

4.1.1. Parameter Setting. The following parameters are set in the GUI of the genetic algorithm, toolbox GADS:

(i) Population type: double-precision vector.
(ii) Population size: 100.
(iii) Create function: uniform distribution.
(iv) Fitness scale transformation: ranking.
(v) Selection operator: roulette.
(vi) Number of elites: 4.
(vii) Crossover rate: 0.80.
(viii) Mutation operator: Gaussian mutation.
(ix) Crossing mode: two-point crossing.
(x) Migration: bidirectional migration.
(xi) Mixed function: fmincon.

Table 1: Hardware requirements.

S. no.	Hardware	Specification
1.	Computer	Dell laptop
2.	Operating system	Windows 10
3.	Core	i7
4.	Processor	2.7 GHz
5.	RAM	32 GB
6.	Generation	11^{th}

(xii) Constraint condition: lower bound: 0; upper bound: 1.

(xiii) Termination condition: algebra: 1000.

(xiv) Fitness limit: 0.

(xv) Stagnation algebra: 100.

Other parameters are set to default values [23–27].

4.1.2. Experiment Steps. Factor set U and comment set V are as follows:

$$\begin{aligned}&U\ (u1,\ u2,\ u3,\ u4,\ u5,\ u6,\ u7) = \{\text{flavor, taste, appearance, packaging, cake size, price, seasoning package, advertising}\},\\&V\ (v1,\ v2,\ v3,\ v4,\ v5,\ v6,\ v7) = \{\text{very dissatisfied, quite dissatisfied, average, quite satisfied, very satisfied}.\end{aligned} \tag{11}$$

Evaluation matrix of male students is as follows:

$$R1 = \begin{bmatrix} 0.36 & 0.50 & 0.12 & 0.02 & 0.00 \\ 0.28 & 0.60 & 0.12 & 0.00 & 0.00 \\ 0.20 & 0.48 & 0.20 & 0.12 & 0.00 \\ 0.20 & 0.38 & 0.22 & 0.20 & 0.00 \\ 0.12 & 0.40 & 0.30 & 0.16 & 0.02 \\ 0.28 & 0.40 & 0.18 & 0.10 & 0.04 \\ 0.32 & 0.40 & 0.16 & 0..08 & 0.04 \end{bmatrix}. \tag{12}$$

Evaluation matrix of female students is as follows:

$$R2 = \begin{bmatrix} 0.46 & 0.39 & 0.12 & 0.01 & 0.03 \\ 0.41 & 0.40 & 0.14 & 0.04 & 0.01 \\ 0.21 & 0.39 & 0.37 & 0.04 & 0.00 \\ 0.13 & 0.33 & 0.39 & 0.10 & 0.04 \\ 0.13 & 0.25 & 0.39 & 0.17 & 0.05 \\ 0.27 & 0.38 & 0.29 & 0..04 & 0.01 \\ 0.27 & 0.37 & 0.35 & 0.00 & 0.00 \end{bmatrix}. \tag{13}$$

Comprehensive evaluation results of males are as follows:

$$B1 = [\,0.23\ \ 0.34\ \ 0.20\ \ 0.18\ \ 0.05\,]. \tag{14}$$

Comprehensive evaluation results of female students are as follows:

$$B2 = [\,0.25\ \ 0.42\ \ 0.23\ \ 0.05\ \ 0.05\,]. \tag{15}$$

4.1.3. Fitness Function Program. According to the composition operator used in the four different models of the fuzzy comprehensive evaluation, the fitness function program was written by using MATLAB language. The Euclidean distance between the comprehensive evaluation results obtained by the genetic algorithm and the actual comprehensive evaluation results of the subjects is taken as the fitness s as shown in the following equation:

$$S = \sqrt{\sum_{j=1}^{m} (d(j) - q(j))^2}, \tag{16}$$

where $d(j)$ is the score of the j^{th} grade obtained by the normalized genetic algorithm, $q(j)$ is the score of the j^{th} grade obtained by the normalized subject's actual comprehensive evaluation, and m is the number of evaluation grades.

4.2. Results

4.2.1. Operators of Composition Operation. The weight and fitness of male students' evaluation of various factors of Master Kang's braised beef noodles under different operator models obtained by the genetic algorithm are shown in Table 2 and in Figure 2.

It can be seen from the table that for males the fitness value of model 1 is the smallest, so it can be considered that males use the synthesis operator $m\ (a,\ V)$ of model 1 in a fuzzy comprehensive evaluation.

The weight and fitness of female students' evaluations of different factors of Master Kang's braised beef noodles using various operators' models developed using the genetic algorithm are shown in Table 3 and Figure 3. For female students, the fitness of model 3 is the smallest, so it can be

Table 2: Weight and fitness under different operator models.

Gender	Model	W1	W2	W3	W4	W5	W6	W7	Fitness
Male	1	0.0525	0.2442	0.3707	0.2695	0.0991	0.2517	0.1446	0.0045
	2	0.0879	0.5328	0.5299	0.8577	0.6416	0.7983	0.1911	0.0173
	3	0.0057	0.0000	0.0181	0.5018	0.1600	0.0410	0.8855	0.0224
	4	0.0000	0.0000	0.0000	1.0000	0.0000	0.0364	0.2995	0.0616

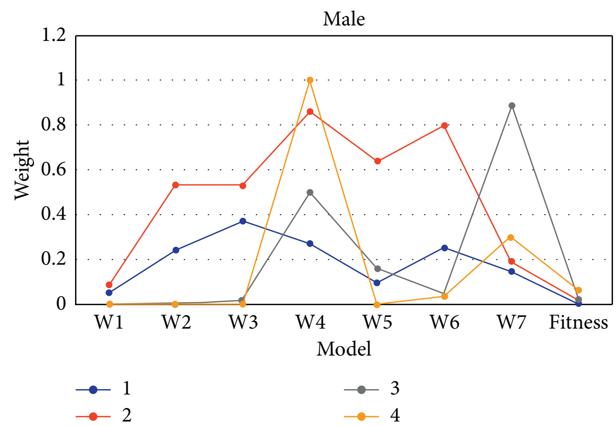

Figure 2: Comparison of weight and fitness for males, under different operator models.

Table 3: Weight and fitness under different operator models for females.

Gender	Model	W1	W2	W3	W4	W5	W6	W7	Fitness
Female	1	0.1379	0.2337	0.260	0.0397	0.0484	0.5134	0.2761	0.0742
	2	0.3197	0.1034	0.3056	0.6168	0.0691	0.9992	0.5201	0.0787
	3	0.3864	0.7506	0.6823	0.3300	0.0329	0.0026	0.0000	0.0616
	4	0.0000	0.9957	0.2063	0.7032	0.0000	0.0003	0.0000	0.0721

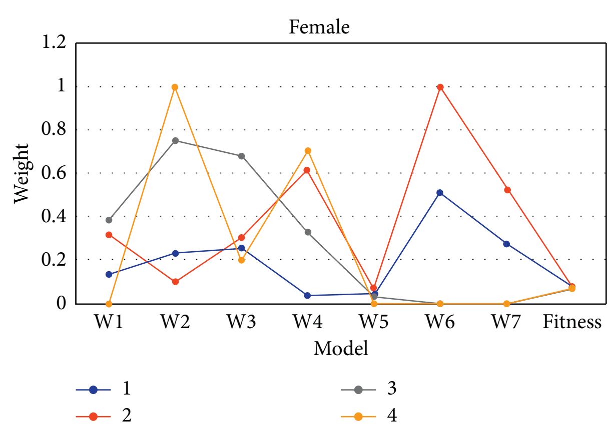

Figure 3: Comparison of weight and fitness for females, under different operator models.

considered that female students use the composition operator m (a, R) of model 3.

4.2.2. A Fuzzy Comprehensive Evaluation of the Weight. The weights of males in model 1 and females in model 3 in Table 1 and Table 2 are normalized, respectively, and the data are shown in Table 4 and Figure 4.

We arranged the data in Table 4 according to the weight and got the weight order of each factor, as shown in Table 5.

The normalized weight of males and females is shown in Figure 4. From W1 through W7, the normalized weights are displayed. This means that the males' weight during W1 is 0.0367, while the females' weight is 0.1769. Similarly, the normalized weight W2 is 0.1705 for males and 0.3436 for females, and so on.

Table 4: Normalized weight.

Gender	W1	W2	W3	W4	W5	W6	W7
Male	0.0367	0.1705	0.2588	0.1882	0.0692	0.1757	0.101
Female	0.1769	0.3436	0.3123	0.151	0.151	0.0012	0

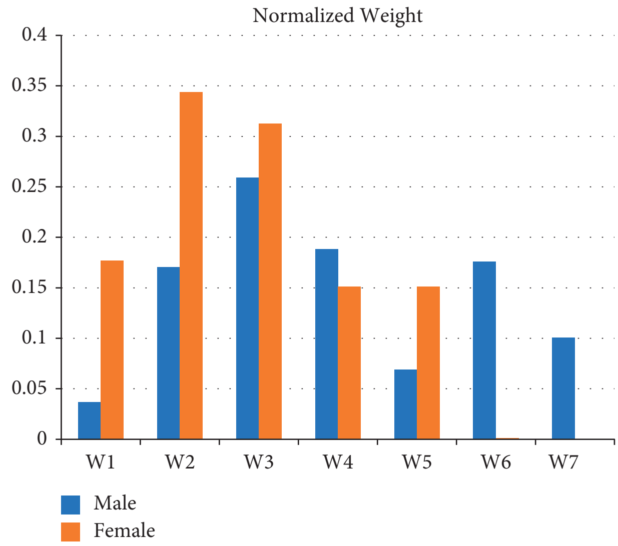

Figure 4: Normalized weight for males and females.

Table 5: Ranking of weights.

Gender	W1	W2	W3	W4	W5	W6	W7
Male	7	4	1	2	6	3	5
Female	3	1	2	4	5	6	7

Both males' and females' ranking weights are shown in Figure 5. From W1 through W7, the ranking weights are displayed. This means that for W1 the males' weight rank is 7 and the females' weight rank is 3, respectively. Similarly, for ranked weight W2, male weight is rated 4 and female weight is ranked 1, and so on.

5. Discussion

5.1. Data Sources. Based on the discussion and questionnaire survey, the instant noodles questionnaire was compiled to investigate the evaluation of students from three universities, including Nanjing Normal University in Nanjing. The subjects were asked to evaluate five separate brands of instant noodles: Master Kong, Uni-President, Jinmailang, Fumanduo, and Rising. With a Likert 5-point scale, they scored their purchase intention from eight aspects: flavor, taste, price, seasoning bag, size of dough, appearance, packaging, and advertising. One-point evaluation means "very reluctant to buy," and five-point evaluation means "very willing to buy." Each brand includes some representative products; for example, Master Kang brand includes braised beef noodles, crab roe lion head, and scallion oil noodles; unified brand includes Haojindao braised beef flavor, Haojindao sauerkraut shredded meat flavor, and Qiaomianguan sour bean beef taste, with a total of 22 varieties of instant noodles. After the preliminary

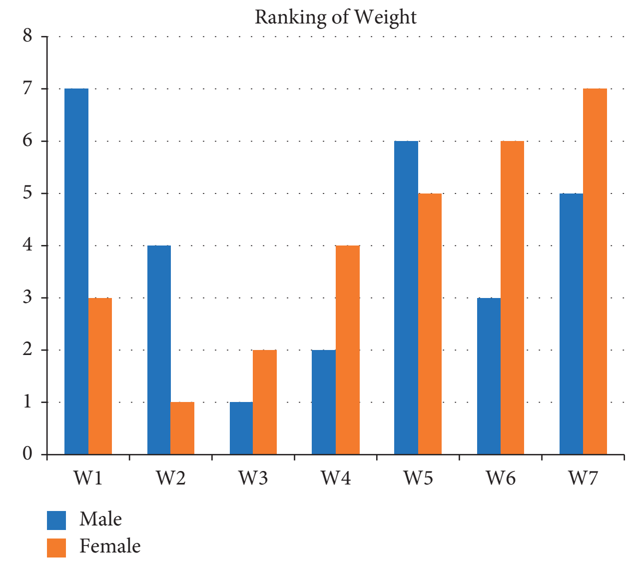

Figure 5: Male and female ranking of weights.

collation of the data, some questionnaires with incomplete data and careless answers were deleted, and 643 valid questionnaires were obtained, including 287 males and 356 females. As a preliminary study of fuzzy comprehensive evaluation based on genetic algorithm in psychological measurement, this paper only analyzes the evaluation data of these college students on Master Kang's braised beef noodles.

5.2. The Use of a Fuzzy Comprehensive Evaluation Method to Evaluate Likert Scale Data Processing. Due to the fuzziness of the subjects' answers from the Likert scale, this study uses the method of a fuzzy comprehensive evaluation to process these data. The Euclidean distance between the theoretical data and the actual data obtained by the fuzzy comprehensive evaluation model is 0.0045 for males, according to an example of college students' evaluation of Master Kang's braised beef noodles. The Euclidean distance between theoretical and actual data for females is 0.0045, while the distance between the two groups of data is 0.0616. That is, the difference between the theoretical and actual data is very small, showing that the fuzzy comprehensive evaluation method can be used to process Likert scale data.

5.3. On the Composition Operator in the Fuzzy Comprehensive Evaluation Method. The conclusion that the fuzzy comprehensive evaluation method can be applied to the data processing of the Likert scale is based on finding the appropriate synthesis operator. It can also be seen from the above calculation results that the Euclidean distance of female data is larger than that of male data, which indicates that a better operator can be found for female data. In essence, the operators of synthetic operations reflect the different characteristics of human cognitive activities in the process of information processing. Therefore, the joint efforts of psychometricians and cognitive psychologists are needed to find better operators.

This study found that males and females use different operators. For the evaluation of Master Kang's braised beef noodles, males use the "max–min" operator in model 1, which only takes the maximum of m as a constant, thus eliminating other factors. This indicates that those males have relatively simple thinking when deciding whether to buy, often only considering the most important factor; if the evaluation of this factor is high, it will produce purchase intention. Females use the operator in model 3, using "bounded sum" (i.e., "addition") instead of the "maximum" operation in model 1. That is to say, all factors have the opportunity to participate in the overall evaluation, and the role of the main factor is not as prominent as model 1. This also shows that those females should think more comprehensively than males when deciding whether to buy. This analysis result is quite consistent with the actual situation.

5.4. Application of the Genetic Algorithm. In this study, a genetic algorithm is used to invert the weight of fuzzy comprehensive evaluation. Genetic algorithm is an intelligent technology of global optimization, which has been successfully applied in the field of computer science and engineering technology, but it is rarely applied in psychological measurement. In the comprehensive evaluation, the weight reflects people's different emphasis on various factors. In essence, it is a psychological problem, but it is difficult for the subjects to express the weight distribution in their mind. This study used a genetic algorithm to search the weight distribution of the subjects' evaluation of Master Kang's braised beef noodles in the whole solution space. This provides a new method for similar research of psychology in the future. However, because the operation of a genetic algorithm is quite complex and many parameters need to be set, this study is to find the more appropriate parameters after many times of debugging. The genetic algorithm itself is still in continuous development, which requires psychologists to conduct more in-depth study and research when applying this method to psychological measurement.

5.5. On Weight Distribution. In this study, a genetic algorithm was used to get the weight distribution of fuzzy comprehensive evaluation of Master Kang's braised beef noodles by males and females. From the calculation results (Table 4), the first two factors males attach most importance to are "appearance package" and "size of dough cake," and the least important factor is "taste," followed by "price." This also reveals that males' thinking when buying instant noodles is relatively simple, if they look at the appearance package from the surface. Whether the "size of the cake" is satisfied or not will decide whether to buy or not, while the "taste," "price," and other substantive factors are largely ignored. It can also be seen from Table 4 that the first two factors that females attach most importance to are "taste" and "appearance packaging," and the last factor is "advertising," followed by "seasoning package." This also shows that those females are more careful and comprehensive than males in purchasing instant noodles. Although they also attach importance to "appearance packaging," they pay more attention to "taste." They believe in their own "taste," but do not believe in external advertising. In addition, it can be seen from Table 3 that the weight of "taste" and "taste" of female students is much higher than that of male students. Female students pay more attention to their subjective taste in the purchase of instant noodles, which also provides good data for psychologists to study the consumption psychology of different gender subjects.

6. Conclusion

The weight vector of the distribution must be determined before the classification issue could be solved with FCE. This research proposed a fuzzy comprehensive evaluation based on genetic algorithms. It outperforms several current Likert scale approaches when it comes to enhancing the efficiency of weight vector computations. The experiments proved that the fuzzy comprehensive evaluation method based on the genetic algorithm can be used to analyze the psychological measurement data of the Likert scale and get the composite operator used by the subjects and the weight distribution of each factor. Furthermore, different genders of college students use different synthetic operators in the fuzzy comprehensive evaluation of instant noodles, and their weight distribution is also different. Additionally, the fuzzy comprehensive evaluation method based on genetic algorithm is valuable for the research of psychological measurement and consumption psychology and meaningful for enterprises. [28].

Data Availability

The data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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Retraction

Retracted: Research on Distance Teaching System of English Course Based on Wireless Network Technology

Scientific Programming

Received 31 October 2023; Accepted 31 October 2023; Published 1 November 2023

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] S. Zheng, "Research on Distance Teaching System of English Course Based on Wireless Network Technology," *Scientific Programming*, vol. 2021, Article ID 3275340, 12 pages, 2021.

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https://doi.org/10.1155/2021/3275340

Research Article

Research on Distance Teaching System of English Course Based on Wireless Network Technology

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The development in technology is taking place with an accelerating pace across the globe. The increasing expansion and advancement in the field of information technology and the modern teaching system provide a technical support for the development of a distance teaching system to learn English courses. Multimedia teaching system of English course based on B/S framework (system 1) and English teaching system based on MVC architecture (system 2) were the two most prominent and widely used approaches for the distance teaching system of English learning courses. These systems comprehensively consider the current English teaching needs, develop the existing architectures, discuss the system architecture and functions, and establish the corresponding development environment. However, the mentioned systems have the problem of high proportion of memory resource consumption and high failure rate of the communicating nodes. In order to reduce the proportion of memory resource consumption and node failure rate of distance teaching system and effectively improve the teaching effect, this study designed a distance teaching system of English course based on wireless network technology. In order to analyze the functionality and stability of the wireless network technology in distance teaching of English course, the server-side and client-side modules of the system are designed. The server side is mainly used to maintain and control the overall functions of the system, while the client side is used to access/request the contents from the server. On this basis, the system software module is designed. The memory consumption results are accounted for under 30%, which is significantly lower than the earlier-mentioned systems, and the node failure rate of the system proposed in this paper does not increase significantly and remains below 4% all the time which indeed is a very low amount of failure rate. The experimental results show that the memory resource consumption ratio and node failure rate of the proposed system are very low, and the application feedback effect is significantly better than the other systems.

1. Introduction

English language has been a focus and need of every researcher nowadays, in order to accomplish their research. The learning of online English (second or foreign language) courses in China, as well as changes in motivation to learn, has gotten a lot of attention as the information age on the Internet has progressed and distance education products are changed significantly [1]. Furthermore, the study findings on motivation in conventional (second or foreign) language classrooms are difficult to adapt to online English classroom learning settings, and different objectives of the online English language learners have come to an end. The conventional static motivational theories struggle to understand and study the process of dynamic changes that takes place with the passage of time [2, 3]. As a result, the problem of demotivation among online English course students in distance education is increasingly becoming a new topic in second language study. Because of the widespread use of computer and network technology, the use of online courses is becoming increasingly popular [4]. It allows learners to learn new skills and abilities without regard to space or time constraints [5]. Massive open online courses (MOOCs) have broadened the applicability range of online remote courses by making course materials available to students all over the world. MOOCs offer a lot of high-quality online courses and other learning resources to students all over the world and are considered as the best platform for global education institutions to share and observe high-quality courses [6].

Learning languages is a fundamental and important ability in the current highly competitive international environment. To meet the needs of social globalization and economic development, higher quality individual's language ability is very important. Language learning necessitates long-term and consistent practice, and an increasing number of students are opting for online open source courses to learn languages and to alive themselves in the modern era competition [7]. According to Beltrán et al. [8], online courses have various characteristics; for example, (i) they provide audiovisual teaching tools, (ii) they adopt the Internet and enable language learners with similar proficiency levels to interact online, (iii) they provision cooperative learning, (iv) they allow language learners to conduct personalized learning at their own pace, and (v) they promote learner autonomy and promote learner autonomy. Numerous scholars have investigated the efficiency of language acquisition through the network environment and online platforms, particularly online open course platforms, over the last years [9, 10]. For example, Ashton and Davies [11] have used peer assessment in the creation of MOOCs to improve the students' educational outcomes. To improve the learning effects, Moreno and Traxler [12] explored the barriers of Mobile Assisted Language Learning, stating that instructors need to modify their mindsets and adopt mobile devices as instruction-assisted instruments. Wang et al. [13] demonstrated that, under the flipped classroom model, online preclass learning might improve learners' speech proficiency.

Internationalization has resulted in a significant increase in cross-national interactions and cooperation, as well as an increase in international activities. As an international language, English has also become an important medium of communication [14]. Further, the social background also makes English teaching more important. The development and advancement of information technology (IT) promote the upgrading of new educational models. Education modernization has become an effective mean to improve the quality of education, and the relevant English distance teaching system has emerged at the right moment [15]. The main goal of English course teaching is to improve students' learning ability and quality of education, and the rapidly developing network technology is the basic way to achieve this goal [16]. Scholars have designed a multimedia teaching system for the English course of the college, based on B/S framework [17]. Their proposed system combines a variety of modes, such as YouTube channels, electronic dictionaries, educational movies, and e-books and monitors the students' learning progress through the way of network logs. Some scholars have also designed an English teaching system based on MVC architecture [18]. Their proposed system comprehensively considers the current English teaching needs, develops the existing MVC architecture, discusses the system architecture and functions, and establishes the corresponding development environment.

The development of wireless network technology-based distance teaching system for English courses not only increases students' knowledge and strengthens interactions between teachers and students, but also allows everybody to communicate with one another and learn from each other without the regard of time or distance. Education curriculum in modern age has had significant ramifications in the field of education. Students' cognitive structure, learning processes, interpersonal interactions, and self-evaluation are all changing in education. The goal of the distance teaching system, which is based on a wireless remote teaching environment, is to allow students to study intelligently. The phrases "loss" and "lost" are similar in Chinese learners of foreign languages. Their linked study is on a smaller scale and occurs less frequently than theirs, and it is still in its infancy in European societies. The research strategy they follow is mostly empirical research. Although their work focuses on contributing variables and the sense of irritation in the EFL learning classroom environment, there are few research approaches that have not yet included motivational elements and learning environments. The earlier-mentioned systems have the problems of high proportion of memory resource consumption and high failure rate of nodes. To solve these problems, a remote English teaching system based on wireless network technology is designed in this study. The main contributions of the proposed work are given as follows:

(i) The purpose of this study is to establish a communication channel between teachers and students and to ensure that the teachers can monitor students' learning status in real time.

(ii) The proposed system comprehensively considers the current English teaching needs, develops a wireless network-based architecture, discusses the system architecture and functions, and establishes the corresponding development environment.

(iii) The proposed system is efficient in terms of both energy and memory and has lesser node failure rate as compared to the existing systems.

The remaining of the paper is structured in the following order: Section 2 represents the related work; Section 3 shows the analysis of application forms of wireless network technology in distance teaching of English courses; Section 4 illustrates the construction and architecture of distance teaching system for English courses; and Section 5 describes the experimental results and analysis. Section 6 concludes the proposed work.

2. Related Work

Online courses are facilities and resources available on the Internet for academic purposes, such as providing learning or teaching materials and allowing teachers and students to communicate with each other for the purpose of exchanging information and valuable thoughts [19, 20]. Online, public, and flexible learning has become the norm in the field of education due to the ubiquity of information and communication technologies [21]. MOOCs first appeared in 2008 and immediately gained popularity across the globe. MOOCs are huge learner-centered open educational resources that are typically defined as free and open digital materials for educators, students, and self-learners to use for teaching, studying, and research [22, 23]. Anybody can engage in MOOCs, get relevant learning tools, communicate with other students, reflect on and share their experiences over the Internet, and share what they have learned with others [24]. According to Comer et al. [25], MOOC and open online courses share the same characteristics; they both are Internet based courses open to all types of learners. Hence, MOOCs are now the newest trend in online learning that facilitates an increasing number of language learners and courses.

Academic researchers claim that, throughout the last few years, technology-assisted language acquisition has emerged as a critical research topic [7, 26]. Because of the advancements in information and network technologies, online language learning has gained popularity. A network environment provides a more individualized learning strategy than the traditional training and methods. For example, Hourigan and Murray [27] stated that learning languages using Blogs enables learners with limited experience to become considerably more confident learners at the early stages. When examining the evolution of technology-based language learning, numerous problems, such as application areas, research aims, and learning methodologies, are vital to consider, according to the Technology-Based Learning model [28, 29]. Research scholars have identified two types of language learning: native language (L1) and nonnative language (L2) learning, in terms of the application area [30]. Some research scholars have looked into online L1 learning in recent years. For example, Phi et al. [31] studied a group of English instructors who took part in teacher training courses and investigated their perceptions of using MOOCs. Huang [32] investigated the academic writing MOOCs and discovered that writing can be considered as a kind of skill development to improve the grammar and surface structure of an article. Similarly, a growing number of scholars have looked into L2 learning in MOOCs, with English as a second language receiving the most interest as compared to the other languages [33, 34]. For instance, Comer et al. [25] looked into the grading of MOOC writing. Their study discovered that a well-structured and effective peer assessment is particularly beneficial in writing MOOCs using quantitative and qualitative analyses.

Some research studies have undertaken reviews of mobile language learning studies as well as digital game-based language learning studies in the recent years [35]. The earlier-mentioned approaches and models have the problem of high proportion of memory resource consumption and high failure rate of nodes which indeed is a serious issue. To overcome the issues in the earlier models and approaches this study mainly focuses on the development of a remote English teaching system based on wireless network technology. The proposed system is considered to be of a great help for the online English learners and academics.

3. Analysis of the Application Forms of Wireless Network Technology in Distance Teaching of English Courses

This section represents the analysis of application forms of wireless network technology-based distance teaching system of English courses. This system is divided into various submodules and is discussed briefly as follows.

3.1. Implementation of Curriculum Teaching. Distance education institutions upload English course learning resources to the learning website, and students can use mobile devices to visit and access the teaching website for learning anytime and anywhere according to their own learning requirements [36]. At the same time, the learning website also provide English course content and learning resources for students to download the resources to assist students in offline learning. When students encounter difficult problems in the learning process, they can choose to use e-mail or submit the problems to the communication platform provided by the learning website and wait for the teacher to answer the questions; at the same time the students can continue their study without any interrupt. The students can also communicate through Tencent QQ and other real-time interaction platforms, by accomplishing real-time communication with other students or teachers.

3.2. Dynamic Release of All Kinds of Educational Information. A variety of dynamic educational information is published on the website for students to browse, including English learning lectures, professional forums, teaching plans, test information, online Q&A time, and so on. In this way, students can learn relevant learning information immediately and get ready to participate in relevant teaching activities [37].

3.3. Online Tests and Quizzes. When students complete a particular level of English learning, they login to the website to take a course test. The test date of English course can be freely chosen by the student, but the test time must be uniform. For objective test questions, the website can directly provide correct answers to the students to check after they make an attempt, while for subjective test questions, the students can only get the evaluation results after the teachers review them, and it is a kind of non-real-time result feedback [38]. In this way, both the teacher and student can master the specific learning situation and provide corresponding learning strategies for the next stage of English course learning.

3.4. Collaborative Learning. In the distance teaching of English courses, it is necessary to provide a cooperative communication platform for students' learning, in order to help students to achieve better results. For difficulty of the problems encountered in the process of learning, the students can submit to the collaborative learning platform through mobile device. Further, the collaborative learning platform uses push technology, the problem to the teachers and the students' mobile devices, the other students and teachers, after receipt of the information that can be aimed at the problem of real-time discussion or solutions. In this way, communication can be effective in real time. Because of this way of learning the students and teachers at the same time in different places on one or more problems can do a detailed discussion, and it is beneficial for both the teachers and students. They can express their own opinions and views, so it truly realizes that the distance education time and space separation, anytime and anywhere learning characteristics, make the distance teaching system as the first priority which is difficult to achieve via the traditional teaching methods [39].

4. Construction of Distance Teaching System for English Courses

This section of the paper represents the methodology followed for the construction of distance teaching system for English courses. The construction process of the distance teaching system consists of various submodules and is discussed briefly in the following subsections.

4.1. Server-Side Architecture of the Proposed System

4.1.1. Working Frequency of Wireless Network and Data Transmission Analysis. Wireless network has a variety of structures, including star-like, tree-like, and mesh topology [40]. The different wireless network topologies are shown in Figure 1. In this study, the tree wireless network topology has been used for the accomplishment of the proposed system.

In the tree network topology, two physical layer standards, 2.4GH and 868/915 MHz, are used, defined by IEEE 802.15.4 standard. Hence, there are three operating frequencies in the system. Both of the physical layers use a unified data format based on the DSSS (Direct Sequence Spread Spectrum). Different operating frequencies are used in different areas, and their modulation means and transmission speed both are different. In the tree wireless network, the 4 GHz band is applied. The 4 GHz frequency band is the global unified frequency band. The use of this frequency band in this paper can reduce the production cost and avoid mutual interference with other wireless communication equipment.

4.1.2. Network Routing Address Assignment Mechanism. There are two kinds of address assignment mechanisms in wireless network topology, such as distributed and high-level address assignment. This paper uses a distributed allocation mechanism [41]. In a wireless network, each device has a relative depth that represents the minimum number of hops required for the device to reach the coordinator. Assume that the coordinator depth is 0, and the first-level child node depth is 1. Nodes can be represented by the maximum depth of cluster tree $T_{\max}$, the maximum number of child nodes $C_{\max}$, and the maximum number of routing nodes per node $N_{\max}$. The calculation formula to determine the address size of $Cskip(d)$ for all routing child nodes of depth D is given as follows:

$$Cskip(D) = \begin{cases} 1 + C_{\max} \times (T_{\max} - D - 1), & N_{\max} = 1, \\ \dfrac{1 + C_{\max} - N_{\max} - C_{\max} \times N_{\max}^{T_{\max} - D - 1}}{1 - N_{\max}}, & N_{\max} \neq 1. \end{cases} \quad (1)$$

In formula (1), $Cskip(D)$ represents the degree of address offset between parent nodes of $D + 1$ layer.

If $Cskip(D) = 0$, then this device belongs to the terminal node in the wireless network and cannot continue to add child nodes. For the terminal node, the address allocation method depends on the network entry order. The calculation formula of the network address of the child node is given as follows:

$$An = \begin{cases} Cskip(D) \times (n-1) + 1, & 1 \leq n \leq N_{\max}, \quad \text{Router}, \\ Cskip(D) \times N_{\max} + n, & 1 \leq n \leq (C_{\max} - N_{\max}), \quad \text{EndDevice}. \end{cases} \quad (2)$$

In formula (2), n represents the number of terminal nodes.

4.1.3. Design of Server and English Curriculum Resource Database. The main work in the process of designing English course resource database is to construct an E-R model, also known as Entity Relationship Diagram. The E-R model provides the information about entity types, attributes, and the relationship between entities, etc. [42]. Rectangles are used to represent entities, ellipses are used to represent the attributes, rhombus is used to describe the relationship between entities, and lines are used to connect related entities together. The E-R model diagram is shown in Figure 2.

The business logic of the system server is used to deal with user requests. Combined with the user needs, the server functions are divided into user management, course management, information management, and some other useful modules.

Browser, data block service, and Web services are used to construct the Web server. The client sends the request for a particular service, the Web server receives the HTTP request sent by the client browser, and after receiving the request it queries the database for further processing. When the browser receives the query result, it will automatically parse JS, CSS, and other files. The function of database server is to store data, and the function of Web server is to access the data and forward the information to the client.

Integrated SSH framework composed of spring, Struts2, and Hibernate technology is integrated into the Web server. Among them, the business logic layer deals with business planning, data access, legitimacy verification, and other tasks. Further, the client completes its interaction with the database after connecting this layer with the components.

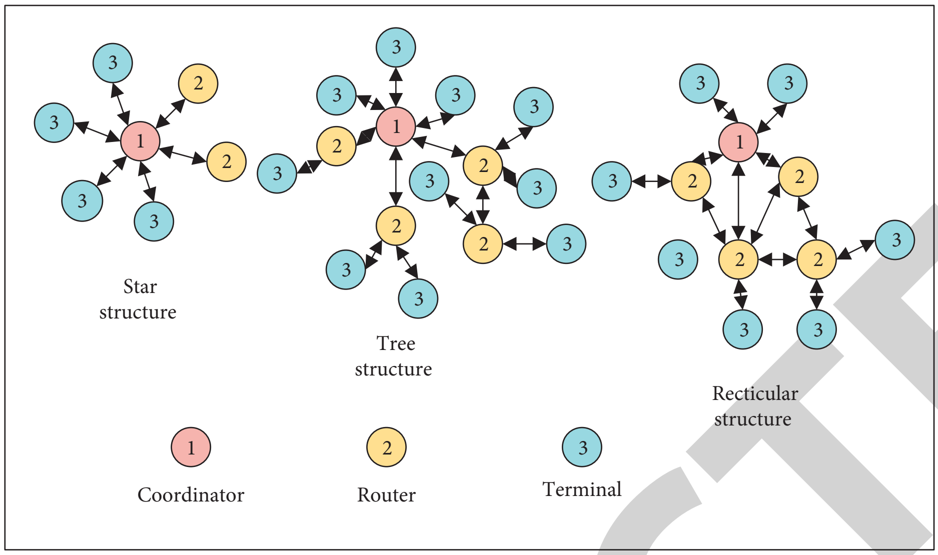

Figure 1: Wireless network topology diagram.

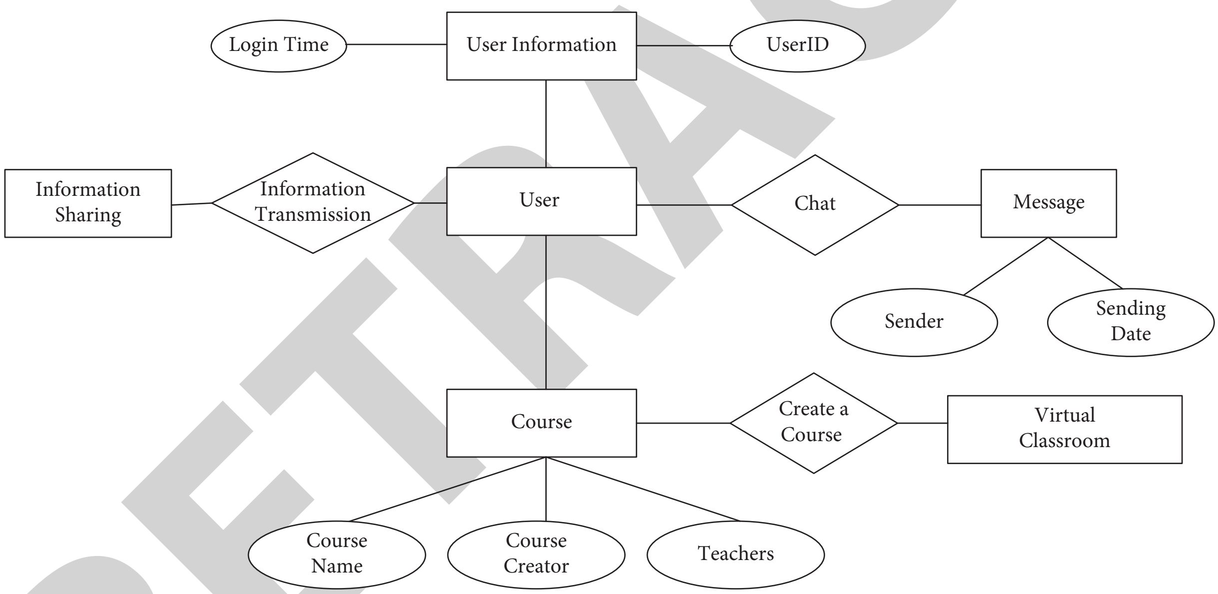

Figure 2: E-R model and relation structure diagram.

On this basis, the interactive Intranet server side and the learning Intranet server side are used to enrich the Web server. Learning modules provide different functions for various targeted groups. In order to reduce the storage space and facilitate network transmission, the system uses FFMPEG multimedia codec framework to automatically convert the video encoding uploaded by the teacher. However, due to the limitations of the format supported by the framework, it is necessary to verify the format.

The Bootstrap front-end development framework based on CSS, HTML, and JavaScript is used in the coding design process to facilitate students to access the teaching module. This framework is a Web front-end CSS framework developed with the help of HTML5 and CSS3 and is compatible with most JQuery plug-ins.

4.2. Client-Side Architecture of the Proposed System

4.2.1. Teaching Module. In the proposed wireless network technology-based distance teaching system for English courses, the teaching mode plays an important role [43]. As a guide, teachers must formulate learning objectives in a planned and systematic way and provide scientific teaching methods to different students. The teaching mode of the English course distance teaching system based on wireless network technology is shown in Figure 3.

The essence of the teaching mode shown in Figure 3 is to introduce wireless network technology into English teaching, emphasizing on the combination of independent learning and classroom teaching. The teaching content includes listening, speaking, reading, writing, and translation,

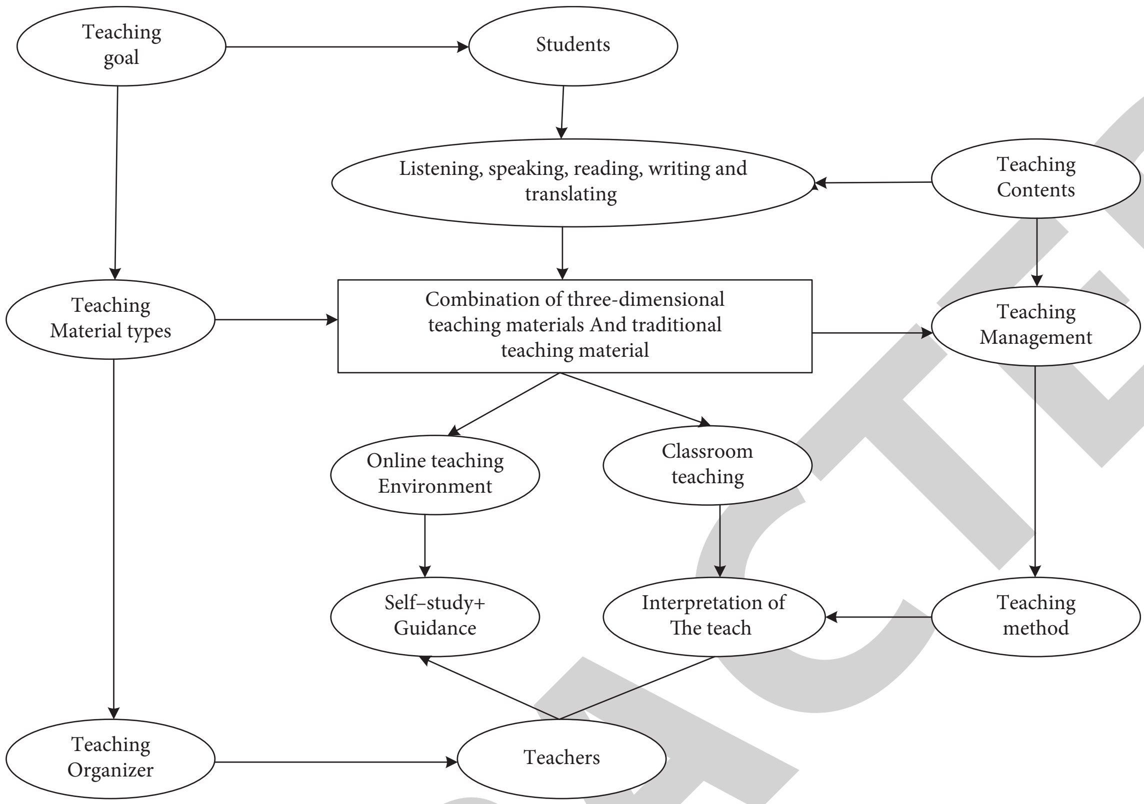

Figure 3: English course schematic diagram based on distance teaching system.

which can be organized separately or integrated together. This new teaching mode takes three-dimensional teaching materials as the carrier, which not only highlights the advantages of Internet based distance teaching, but also highlights the main position of students. Under the above teaching mode, the teaching strategy maximizes the efficiency of English learning, enhances the learning effect, ensures the comprehensive and balanced development of all kinds of skills, cultivates students' independent learning ability, and at the same time does not give up the advantages of traditional classroom teaching in order to realize the teacher-oriented teaching process management.

4.2.2. Teaching Effect Detection and Evaluation Module. As a tester of learning outcomes, teachers should guide students to pay attention to autonomous learning [44]. Through the evaluation and record of students' achievement and performance in the teaching process, the students are comprehensively evaluated to reflect the real level and stimulate the enthusiasm of students in learning.

(1) Classification of Assessment Information. Achievement detection and evaluation in the wireless network environment not only obtain students achievement comprehensively, but also carry out multidimensional and multigranularity diversified analysis on students' achievement. The relevant data to be used for online teaching testing and evaluation mainly include English teaching basic information and student achievement data.

(a) Basic information

Basic Information of Teachers: Teachers are represented by T and are expressed as follows:

$$T = \left\{ t | t \in \prod_{i=1}^{N} \operatorname{dom}(a) \right\}. \tag{3}$$

In formula (3), a is the attribute set of basic information of teachers, including name, ID number, teacher's service number, gender, professional title, and educational background, where $\operatorname{dom}(A)$ is the domain of attribute components.

Basic Information of Students: The student set is described by S, and its expression is given as follows:

$$S = \left\{ s | s \in \prod_{i=1}^{N} \operatorname{dom}(b) \right\}. \tag{4}$$

In formula (4), b is the set of basic information attributes of students, including name, ID number, gender, contact phone number, and e-mail address.

Course Information: Course set is expressed by C, and its expression is given as follows:

$$C = \left\{ c | c \in \prod_{i=1}^{N} \operatorname{dom}(m) \right\}. \tag{5}$$

In (5), m includes both course number and course name.

(b) Student achievement information

Types of Achievement Information: The student achievement information is expressed by G, and its expression is given as follows:

$$G = \left\{ g | g \in \prod_{i=1}^{N} \operatorname{dom}(d) \right\}. \quad (6)$$

In formula (6), d is the set of information attributes related to grade type, including number, subject, test name, weight, and remarks information.

Score Information: The score information set is expressed as E, and its expression is given as follows:

$$E = \left\{ e | e \in \prod_{i=1}^{N} \operatorname{dom}(i) \right\}. \quad (7)$$

In equation (7), i includes student number, name, total score, and time.

(c) Assessment information acquisition

There are many ways to obtain students' English scores. This paper mainly obtains data from the following aspects and then evaluates them.

Classroom Performance Information: Students' classroom performance refers to the performance of emotion, psychology, and attitude brought by teaching in class [45]. In the process of distance teaching, teachers can evaluate students according to their participation, English course preview, and teamwork ability, save the data, and present it to students, which not only are convenient and fast, but also can ensure that the data will be safe and secure and will not be omitted.

Homework Information: Homework information is considered as one of the most intuitive data types for students to evaluate their English scores. In the wireless network environment, the speed of students' finishing English homework and the situation of wrong questions can be recorded, so as to show students' mastery of knowledge points more comprehensively. When it comes to the evaluation of homework of the students, the objective questions can be corrected and evaluated automatically by the system, while the subjective questions will be checked by the teachers. The scores will be saved in the database, which can be checked by the teachers and students at any time when required.

English Test Information: English test information and homework information both are similar; it is an intuitive data and can play a good role in feedback assessment. Students use the detection system to complete the English test, after the teacher's correction records in the database.

All evaluation data of English course teaching based on wireless network can be obtained by using the above methods, and the detection and evaluation of students' English scores can be completed through the system processing method as shown in Figure 4.

4.3. Design of the System Software

4.3. Design of the System Software. Communication and interconnection between various parts of the system is done by using the software designed for this study, which not only realizes the communication with the mobile terminal, but also is combined with the teacher client setup. The most important thing in the system software design is to formulate the communication protocol of each part.

4.3.1. Communication with the Mobile Terminals. The format of the mobile terminal sending to the touchpad is shown in Table 1. In Table 1, computer name and user name represent device name and user name, respectively, which are used to identify the sender of information. Action1~Action4 represent four-point touch action, including two types of press and bounce; Point1~Point4 are four-point coordinates.

An integrator is set in the system, and the client transits the touch signal to the integrator. The touch points include horizontal and vertical coordinates and other information. As long as the synchronous touch of four points is handled, communication with the mobile terminal can be realized.

4.3.2. Communication with the Teacher Client. The purpose of communication between the integrator and the teacher end includes informing the teacher end of IP address and receiving split screen information set by the client end. For example, when teachers assign tasks and ask two students to answer at the same time, students can directly give answers on their own mobile terminals and display them on the big screen. One student's answer will be in the left half, while the other student's answer will be on the right half, and the two categories will not interfere with each other. The realization process of this function is as follows:

Step 1. Unify coordinates: The resolution of different terminals is inconsistent with the coordinate range, so it needs to be normalized. According to the touch range of the touch screen of 1920×1080, this paper maps all the touch coordinates of mobile terminals to this range, and the calculation formula is as follows:

$$x1 = \frac{\text{Input} \cdot x \times 1920}{\text{Screen } X}, \qquad y1 = \frac{\text{Input} \cdot y \times 1080}{\text{Screen } Y}. \quad (8)$$

In the above formulas, Screen X and Screen Y represent the maximum values of horizontal and vertical coordinates, and Input.x and Input.y are the initial touch coordinates.

Step 2. User number:

$$\text{Loc} = \text{hash}(\text{UserName}). \quad (9)$$

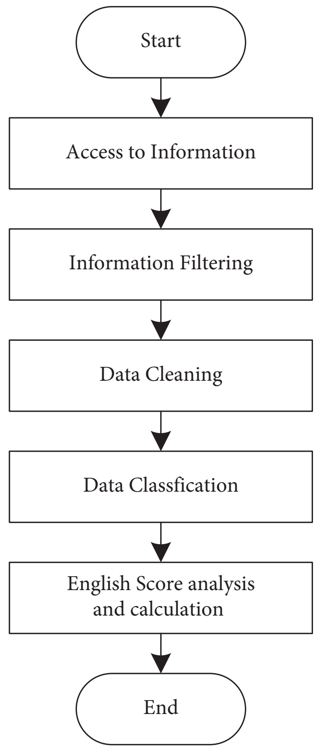

Figure 4: Flowchart of students' English score detection and assessment.

Table 1: Touch data format information.

Data types	Field names	On behalf of the meaning
String	Computer name	Device name
String	User name	User name
Action	Action 1	Action 1
Action	Action 2	Action 2
Action	Action 3	Movement 3
Action	Action 4	Action 4
Point	Point 1	Coordinates 1
Point	Point 2	Coordinate with 2
Point	Point 3	Coordinates of 3
Point	Point 4	Coordinate 4
Int	Point C	Total number

The data sent by the mobile terminal to the integrator contains the user name, which is unique and can be used to accurately determine the number of the coordinate mapping region in the touch data by Hach voting.

Step 3: Coordinate mapping: If the split screen is not set by the teacher, multiple students will share the same touch area. After the split screen setting is completed, the students' touch area can be mapped to a part of the PC's touch screen, so that there will be no interference when multiple students touch at the same time. Its calculation formula is given as follows:

$$\begin{aligned} fX &= f\%W, \\ fY &= \frac{f}{W}, \\ \mathrm{TC}\cdot x &= 1920 \times \frac{fX}{W} + \frac{x1}{W}, \\ \mathrm{TC}\cdot y &= 1080 \times \frac{fY}{H} + \frac{y1}{H}. \end{aligned} \tag{10}$$

Among the above formulas, f represents the screen sequence number, W and H represent the number of columns and rows in the divided area, fX and fY represent the number of rows and columns in the student's touch control area, $x1$ and $y1$ represent the normalized horizontal and vertical coordinates, and $\mathrm{TC}\cdot x$ and $\mathrm{TC}\cdot y$ represent the finally calculated touch coordinates.

After completing the above steps, the software module design of the system will be completed, thus realizing the interactive teaching between teachers and students in the distance teaching department of English courses.

5. Experimental Results and Analysis

This section of the paper represents the experimental results carried out via different experiments and the analysis of those results. In order to verify the practical application effect of the wireless network technology-based English course distance teaching system designed above, different experiments are conducted.

The test tool selected to carry out the experimental and simulation results is the Mercury Load Runner 6.0 to simulate user access, keeping the parameter settings unchanged from the actual operating environment. In order to avoid the uniformity of the experimental results, the traditional B/S frame-based multimedia English teaching system in colleges (system 1) and universities and the MVC frame-based English teaching system (system 2) are compared with the system designed in this study (proposed system).

Firstly, the memory resource consumption performance of different systems is compared, and the results are shown in Figure 5.

According to the experimental results shown in Figure 5 one can clearly see that the system proposed in this study, i.e., the design of English course of remote teaching system based on wireless network technology showed good results in terms of memory resource consumption. The memory consumption results are accounted for under 30%, which is significantly lower than the other two systems used in the literature, i.e., B/S framework of college English multimedia teaching system (system 1) and English teaching system based on MVC architecture (system 2). Performance of the proposed system was superior in terms of memory resource consumption as compared to the other two systems. Among the two other systems the performance of system 1 was

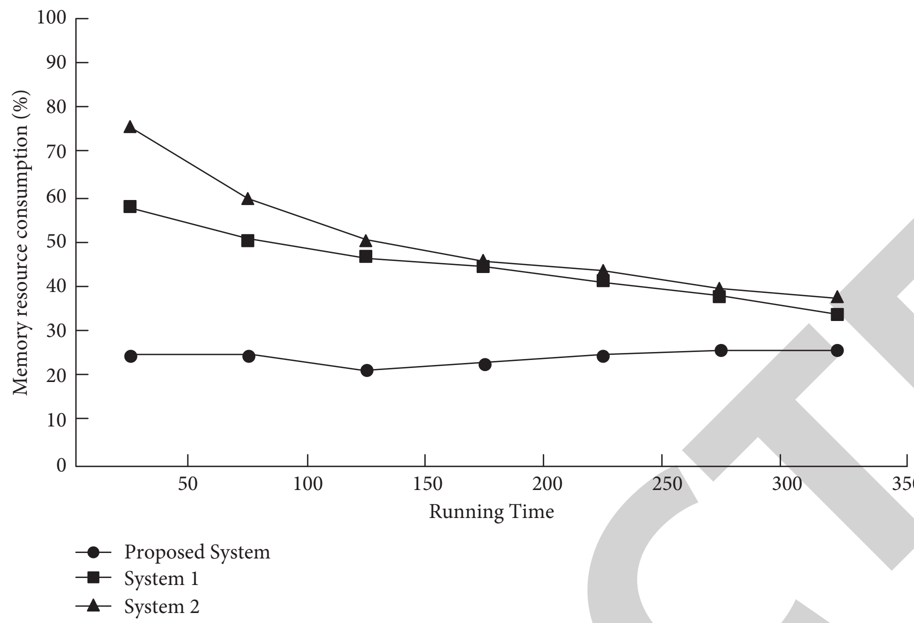

Figure 5: Comparison of memory resource consumption of different systems.

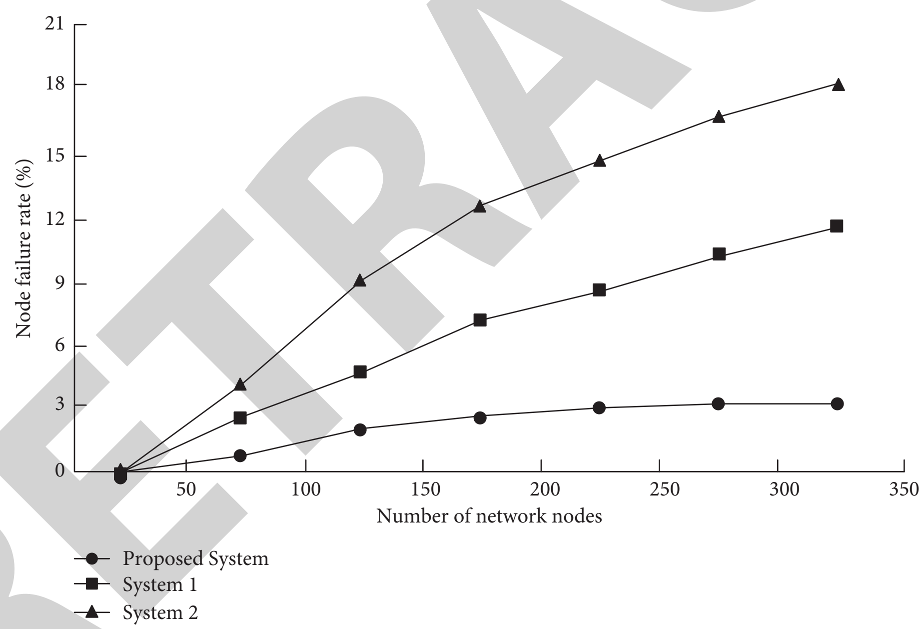

Figure 6: Node failure rate diagrams of different systems.

better than that of system 2 in terms of memory resources consumption. System 2 consumes more memory resources and stood last in the performance competition.

In another experiment a PC connection module is used as a network coordinator to add 350 student nodes. In the process of issuing the transmission command, the state of each student node is presented on the software. The stability of the network is observed through the state of student nodes. The node failure rate was used as an indicator to verify the network stability of different systems. Figure 6 shows a comparison of system 1 and system 2 with the proposed system.

It can be seen from Figure 6 that, with the continuous addition of 350 student nodes, the node failure rate of the system proposed in this paper does not increase significantly and remains below 4% all the time which indeed is a very low amount of failure rate. The performance results indicate that the proposed system is stable and efficient as compared to the other two systems used in the literature.

According to the students' learning interest, memory of words and grammar, degree, interaction between teachers and students, user satisfaction and degree of system operation, questionnaire survey of 100 students, and the questionnaire results used in this study are shown in Table 2.

Table 2: Experimental class questionnaire statistical table.

		Number (person)	Proportion (%)
Students' interest in learning	Commonly	5	5
	Very good	95	95
Memory of words and grammar	Commonly	3	3
	Very good	97	97
Teacher student interaction	Commonly	6	6
	Very good	94	94
Customer satisfaction	Commonly	2	2
	Very good	98	98
System operation simplicity	Commonly	2	2
	Very good	98	98

By analyzing the data shown in Table 2, one can see that the distance teaching of English course based on wireless network technology designed in this study showed good performance in terms of all the mentioned characteristics, i.e., student interest in learning, memory of words and grammar, teacher student interaction, customer satisfaction, and system operation simplicity. At the same time, after the application of this system, the interaction between teachers and students was noticed and was considerably good as compared to the other systems, and most of the students were satisfied with the teaching effect and think that the system is convenient to operate. It is anticipated that the proposed system will be of a great help for the academic and educational societies in learning the English courses remotely with an ease.

6. Conclusion

With the growing popularity of online learning and the strengthening of online learning activities, a considerable amount of semistructured data has been gathered on different learning platforms. There are several forms of data. People can analyze and categorize the underlying stats behind it, which helps in the improvement of teaching strategies. Different systems have been developed in the past for the distance teaching learning courses. Among the developed systems the two most widely used systems are (1) multimedia teaching system of English course based on B/S framework (system 1) and (2) English teaching system based on MVC architecture (system 2). This system performed well in terms of the recent English teaching needs, developing the existing architectures, discussing system functions, and establishing the corresponding development environment. These systems were posed to some major problems, i.e., high memory resource consumption and higher failure rate of the communication nodes. In order to overcome the limitation of the earlier approaches and to optimize the online teaching effect of English course, this paper designs a distance teaching system of English course based on wireless network technology and achieves good application effect. The proposed system showed good results in terms of memory consumption, i.e., below 30%, and nodes failure rate which is below 4%. The experimental results show that the memory resource consumption ratio and node failure rate of the proposed system are very low, and the application feedback effect is significantly better than the other systems. In the next step of research, we will continue to collect feedback, obtain the latest needs of users, upgrade the teaching resource database of the system, and further improve the quality of English distance education. In addition, the connection of more clients at a time to the distance teaching system is also one of the future works of this study.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

There are no conflicts of interest concerning this work.

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Research Article

A Convolutional Neural Network (CNN) Based Approach for the Recognition and Evaluation of Classroom Teaching Behavior

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To improve classroom teaching behavior recognition and evaluation accuracy, this paper proposes a new model based on deep learning. First, we obtain the classroom teaching behavior characteristic data through the SVM's linear separable initial and determine the relationship of the characteristic sample data in the hyperplane. Then, we obtain the heterogeneous support vector of the online learning behavior characteristic sample data in the SVM's hyperplane and complete the extraction of data with the help of convolutional neural networks. We then use a decision matrix to analyze the hierarchical process, determine the weight of classroom teaching behavior indicators, verify their consistency, and complete the evaluation by calculating the membership of evaluation factors. The experimental results show that the identification and evaluation method of classroom teaching behavior in this paper can effectively improve the identification accuracy of the classroom teaching behavior.

1. Introduction

In the realm of education, recognizing classroom teaching behavior has long been a study emphasis. Teachers in conventional classrooms assess students' learning levels by watching their behavior and then providing teaching feedback. However, this technique is time-consuming and labor-intensive, and it cannot satisfy the demands of today's intelligent learning environment for large-scale classroom analysis [1]. As a result, it is critical to investigate artificial intelligence technologies for automatically identifying student's classroom behavior. This study has significant implications for enhancing classroom teaching quality and assisting educational decision-making and administration. The advent of the big data age has caused information to expand at an exponential rate. One of the key issues in big data analysis is how to use these data in a reasonable and efficient manner [2]. Artificial intelligence technologies can effectively screen data and turn abstract data into useful knowledge. Deep learning, which has recently gained popularity, offers a solution to this problem. Deep learning offers greater accuracy, can automatically extract information, is more adaptable, and is easier to develop than standard machine learning algorithms. Deep learning in education is steadily increasing as the deep learning movement grows. Teaching activities have long been the most important and fundamental activities in school education research, as well as the most important component of the school's teaching and educating function. The classroom behavior of students will immediately reflect the instructional effect. As a result, analyzing students' classroom behavior will aid in the improvement of teaching and classroom management. Students' classroom behavior may be divided into two categories: classroom engagement and general classroom environment. Nonlearning behavior is the other. Teachers create an effective appraisal of students in the conventional classroom by watching students' class status and assignment completion in the classroom. However, because it is impossible for teachers to monitor all pupils in a systematic and comprehensive manner, the teaching impact has not been fed back in time, prompting the development of a recording and broadcasting system. The problem has been alleviated to some extent. The conventional technique of analyzing instructor and student behavior is still a manual observation of instructional films, which is time-consuming, tedious, and inefficient [3]. At this time, society has entered a more intelligent epoch. The transition of the education sector will be unavoidable, whether it comes from the exterior organizational structure or the core internal content. The reform will be focused on intelligent education and intelligent management among them. One of the technological topics that needs to be explored in the future is how to utilize intelligent teaching to develop effective classroom evaluation and enhance teaching quality. It can assist instructors to enhance their teaching to a large amount by solving the problem of teachers finding it difficult to watch each student's classroom behavior in detail [4].

Zhao et al. [5] proposed a multidimensional feature fusion-based intelligent analytic technique for training behavior. This method creates a multidimensional feature fusion intelligent teaching behavior analysis mode, with four core elements: "visual auditory feature-based teaching behavior analysis coding system, auditory feature recognition of teaching behavior, visual feature recognition of teaching behavior, and visual presentation of data in the teaching analysis process." They then proposed three realistic paths: "visual feature-based," "auditory feature-based," and "fusion feature-based." They preliminarily analyzed 43 classroom teaching videos, extracting the visual characteristics of teaching behavior in the time dimension, to provide a reference for teaching behavior intelligent analysis activities such as "one teacher, one pedagogy." This approach has a strong theoretical foundation and a broad influence in practise, but it still needs to be refined. A follow-up study [6] suggested a compound feature and deep learning-based classroom teaching behavior recognition system.

To address the limitations of the preceding techniques, this study uses a convolutional neural network to identify and evaluate classroom teaching behavior in order to improve teaching quality and contribute to educational growth. In our work, we use the crowd as the main object, extract the crowd's static information using the foreground extraction method, obtain the crowd's dynamic information using changes in crowd movement, use the CNN model to learn two different crowd behavior characteristics, and then combine these two characteristics to analyze the spread. Population behavior analysis is influenced by the location and interval of population data extraction.

According to the experimental results, these two population characteristics can better characterize population status in the geographical dimension and population change in the temporal dimension. Data intervals and locations that are reasonable can significantly increase the expressive ability of crowd data. Finally, existing crowd behavior analysis approaches are compared to the suggested method. The suggested approach's efficiency is confirmed by quantitative and qualitative testing findings, which demonstrate that the proposed method can provide a better confusion matrix and higher accuracy. This approach offers a high level of accuracy when it comes to teaching behavior recognition. There are still some modifications in the identified items; therefore, the recognition and assessment cannot be done simultaneously.

2. Extraction and Identification of Classroom Teaching Behavior Characteristics

2.1. Extraction of Classroom Teaching Behavior Characteristics. Teaching behavior research has progressively grown into a distinct study subject since the mid-twentieth century. It has steadily concentrated on the microlevel of classroom instruction in recent years. Classroom teaching behavior is a multilevel and intricate synthesis of subject interaction behavior in the classroom. It differs from teaching concepts and ideas in that it is explicit, dynamic, individual, intentional, and situational, with several categories [7]. It primarily consists of teaching, auxiliary teaching, and classroom management. Scholars combine several categorization bases to create a wide range of categories, as shown in Table 1.

Based on the classification, the classification of classroom teaching behavior mainly focuses on the essential elements in the classroom, including teachers, students, teaching content, and teaching media (complex media and soft media). Habermas, a social theorist, once proposed that human communication activities exist between more than two subjects with language ability and actionability, and there is a relationship between speech and external action among subjects. Classroom teaching activities are interactive activities between teachers and students in classroom scenes. To achieve common classroom goals, the sum of teaching, learning, and other related behaviors in interactive activities is collectively referred to as classroom teaching behavior. Therefore, the author divided classroom teaching behavior into teachers' teaching behavior, students' learning behavior, and other behaviors.

Teaching behavior is considered the behavior taken by teachers and students to achieve certain teaching objectives in the teaching process. Teachers' classroom teaching behavior refers to all the interactions between teachers and students in the classroom and the behavior related to teaching and learning. Since teachers and students are the composite subjects of educational activities (including teaching), based on the above definitions of experts, classroom teaching behavior is the sum of teachers' teaching, students' learning, and other related behaviors in the classroom environment to achieve common mathematical goals [8]. Based on the above classification results, its characteristics are extracted first to realize the recognition and evaluation of classroom teaching behavior.

Table 1: Classification of classroom teaching behavior.

Classification basis	Result
Media tools	Speech, nonverbal, intuitive, and guiding behavior
Interaction between teachers and students	Teacher-independent, student-assisted
Behavior occurrence matrix	Normal teaching, dynamic teaching, and witty teaching behavior
The order in which the classroom teaching behavior occurs	Preclass, classroom, and after-class teaching behavior
Teacher and student performance	Statement, guidance, presentation, questions, feedback, management, observation, listening, etc.
Get results	Effective teaching and ineffective teaching

In the extraction of classroom behavior, SVM [7, 9] has been extensively used in the existing literature. The classroom teaching behavior feature data are regarded as a collection of finite samples in the two-dimensional space, and the data are initially obtained through SVM linear segmentation. Assuming that the sample set, A of the feature data, is $\{(a_1, b_1), (a_2, b_2), \ldots, (a_n, b_n)\}$, the classroom teaching behavior feature sample data appear in the hyperplane as follows:

$$\begin{cases} A\colon V^T a + B = 0, \\ A_1\colon V^T a + B = 1, \\ \quad \ldots, \\ A_n\colon V^T a + B < 1. \end{cases} \tag{1}$$

In the formula, v represents the normal vector of the characteristic data within this space, B represents the location of the data in the space, and A_1, A_n represent the support vectors of the two hyperplanes, respectively.

To ensure the maximum [10] of classroom teaching behavior feature data in the hyperplane, it should meet

$$\begin{cases} S.T.B_i\left(V^T E_i + B\right), \\ MIN\dfrac{1}{3}\|V\|^2. \end{cases} \tag{2}$$

In the formula, E_i represents the Lagrange multiplier.

Furthermore, the classroom teaching behavior characteristic data exist in the SVM hyperplane, and the characteristic sample data are expressed as [8]

$$C = \frac{V^T (1 - B + 1(U))}{\|V\|}, \tag{3}$$

where C represents the heterogeneous class support vector values of characteristic data.

Due to many factors, the characteristic data of classroom teaching behavior cannot always maintain a linear separable state. Therefore, we should also consider the nonlinear characteristics formed by some external factors [9]. The nonlinear characteristics of classroom teaching behavior characteristic data can be transformed into linear separable data by reducing the dimension of the data in the hyperplane. The nonlinear data features obtained after calculation are minimized to convert the nonlinear data features of classroom teaching behavior data into the minimum value; that is,

$$\begin{cases} \mathrm{S.T.}b_i\left(R^T f(e) + d\right) > 1, \\ i = 1, 2 \ldots n, \\ \mathrm{MIN}\dfrac{1}{3}\|R\|^2. \end{cases} \tag{4}$$

The feature data of classroom teaching behavior are first obtained using SVM linear separability, then the relationship of feature sample data in the hyperplane is determined, the heterogeneous support vector of online learning behavior feature sample data in the SVM hyperplane is obtained, and the feature data extraction is completed.

2.2. Recognition of Classroom Teaching Behavior Based on Artificial Intelligence. The combination of AI and learning science has given rise to a new field—educational artificial intelligence (EAI). A large number of EAI systems integrating AI technology, e.g., data mining, have been applied to schools for efficient utilization of big data generated within the campus by analyzing and predicting students' learning performance. It provides students with more personalized and diversified learning. AI technologies widely used in the field of education include image recognition, speech recognition, semantic recognition, and machine translation. Therefore, this paper uses a deep learning-based method named convolutional neural network to recognize classroom teaching behavior [11].

CNN is one of the most successful fields in deep learning algorithm applications, mainly composed of convolutional, pooling, and full connection layers. In addition, some common layers, such as the activation function layer, can significantly reduce the network training time, enhancing the generalization ability of the network and preventing the dropout layer with an overfitting problem. CNN is a hierarchical model, where first, the original data are extracted through the convolutional layer. The pooling layer then takes the dimension reduction data as the input of the lower convolution, repeating the convolution and pooling operation. The high-level semantic information in the original data is gradually transmitted from low to high to the last level. The relevant parameters are updated by calculating the difference between the actual and predicted values and then combined with the backpropagation algorithm, thus yielding a convergence model [12]. Its basic structure is shown in Figure 1.

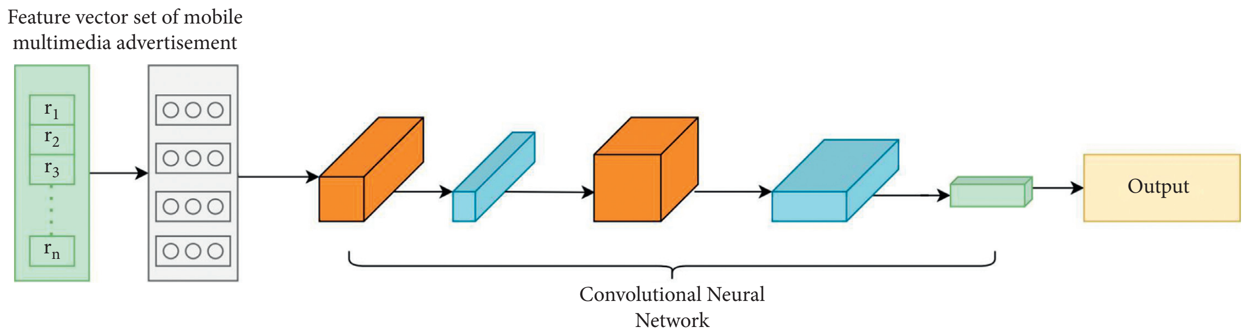

Figure 1: Basic structure of the proposed model.

In classroom teaching behavior recognition, the core of constructing a convolutional neural network is the convolution layer. After smoothing the input signal through the convolution kernel and filter, it is biased to extract local image features. The depth of each convolution kernel is consistent with the input data, so the convolution kernel smoothes along the height and width to map a new feature map. The eigenvalues extracted in the first few layers mainly refer to low-order features such as vertical and horizontal edges. The latter layers combine the low-order features into high-order ones. These high-order features can distinguish these data and map them to the category space for classification operation. At this time, the mapped classroom teaching behavior data matrix is

$$S = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ \vdots & \vdots & S_{ij} & \vdots \\ S_{m1} & A_{m2} & \cdots & S_{mn} \end{bmatrix}. \tag{5}$$

According to the data matrix obtained from the convolution layer, we determine the processing parameters of the pooling layer. Compared with the convolution layer, there are no parameters to learn, select the maximum value or mean value from the target region, and then form these maximum values or mean values into a new feature map. Pooling is essentially a process of downsampling to reduce the number of parameters to reduce the computational complexity of the network. To some extent, it can prevent overfitting problems [13]. Pooling is to reduce the spatial operation of the target area without changing the number of channels of input and output data. Moreover, when the data change slightly, pooling will return the same result, which enhances the robustness of the network. At this time, the recognition result is

$$L_i^{n+1} = \frac{1}{q}\sum |P - S|\frac{C}{Z}. \tag{6}$$

Input the recognition result data obtained above to the last layer of the CNN as the full connection layer, which is connected with all the feature images of the previous layer and usually converts the two-dimensional image output by convolution into a one-dimensional vector. Because the full connection layer does not retain the spatial information of the image, it cannot maintain the spatial structure and then change the high dimension into the low dimension through dimension transformation while retaining helpful information. In the CNN, the full connection layer takes the feature vector as the classifier's input to obtain the output of the corresponding category to realize the original data's recognition. At this time, the output classroom teaching behavior recognition results are optimized by the objective function to obtain

$$f(z) = \frac{1}{1 + e^{l}}. \tag{7}$$

In the formula, $f(z)$ represents the ultimately obtained identification results, and e represents the corrected error value.

In the recognition of classroom teaching behavior, we use a convolutional neural network, pooling layer, and full connection layer to get the recognition of classroom teaching behavior with the help of the objective function.

3. Research on Classroom Teaching Behavior Evaluation

Based on the above identified classroom teaching behavior, we carry out the evaluation analysis of classroom teaching behavior. Firstly, the weight of classroom teaching behavior data is calculated by constructing the confusion matrix.

The hierarchical structure can reflect the relationship between factors. Using the analytic hierarchy process to form a decision matrix is a quantitative treatment of subjective judgment based on qualitative judgment. It is an essential step from qualitative to quantitative analysis. Because at the standard level, each standard occupies a different proportion in the minds of different decision makers. To ensure the quality of the obtained index judgment, the classroom teaching evaluation questionnaire and index scoring scale were distributed to 7 experts of the speciality, who were invited to compare and score the indicators. The questionnaire results were summarized and statistically combined with the judgment given by the experts to form a matrix [14].

Now, the n comparison factors, $X = (X_1 \ldots X_2)$, have the effect of an uncertainty factor 2. To provide real and credible data for the study, we will establish the comparison matrix by comparing the two factors to each other. Two factors in each comparison and the full comparison results are represented by the matrix:

$$A = \left(a_{ij}\right)_{n*m}. \quad (8)$$

We can represent the $Z - X$ confusion matrix as

$$a_{ij} = \frac{1}{a_{ij}}. \quad (9)$$

According to the above constructed confusion matrix, we complete the determination of the weight of classroom teaching behavior as

$$G[f] = \int H\left(\sum_{i=1}^{k} \varepsilon_k\right) q\mathrm{d}z. \quad (10)$$

In the formula, $G[f]$ represents classroom teaching behavior weights, H stands for the number of judgments, and ε_k represents the scale factor.

According to the above determined classroom teaching behavior weight value, to achieve its evaluation, it needs to calculate its consistency as

$$w_i = \sum_{j=1}^{m} b_j c_{ij} \quad (i = 1, \ldots n). \quad (11)$$

The weight randomness of classroom teaching behavior data is

$$CR = \frac{\sum_{j=1}^{m} b_j CI_j}{\sum_{j=1}^{m} b_j RI_j}. \quad (12)$$

Based on this, classroom evaluation is divided into two evaluation subjects to evaluate the classroom with peer teacher evaluation and expert evaluation [15]. Suppose the total collection of classroom evaluation is U, peer teacher evaluation is U_1, and expert evaluation is U_2; then, the classroom teaching evaluation can be expressed as follows:

$$U = \{U_1, U_2\}. \quad (13)$$

The set of evaluation factors in evaluation is set to

$$U_1 = \{U_{11}, U_{12}, U_{13}, U_{14}\}. \quad (14)$$

At this time, the subset of the classroom teaching behavior membership is constructed as follows:

$$R_i = (r_{i1}, r_{i2}, \ldots r_{im}), \quad (15)$$

where R_i represents the evaluation indicators in the evaluation collection and r_{i1} represents the membership of the evaluation elements. The final evaluation results of the classroom teaching behavior can be shown by the following equation:

$$r_i = \frac{v_i}{p_n}, \quad (16)$$

where r_i represents the evaluation value, v_i represents the number of factors evaluated, and p_n represents the number of factors evaluated.

In the evaluation of the classroom teaching behavior, we first construct the confusion matrix through the hierarchical analysis method, then determine the weight of the classroom teaching behavior indicators, verify their consistency, and complete the evaluation of the classroom teaching behavior.

4. Experimental Analyses

To verify the scientific effectiveness of the proposed method, in this section, we perform various types of experiment and present the results.

4.1. Experimental Environment. In the experiment, 100 English students majoring in English in the 20th grade of a university were selected as the experimental objects to collect the classroom teaching behavior data of students in the major and identify and evaluate their classroom teaching behavior with the number of students raising their hands, the number of students answering questions, and students' positive behavior research data. The operating system is Nvidia 1050 GPU with 8 GB of memory. The number of experimental iterations is 100, and the data processing results all process the experimental data through SPSS.

4.2. Experimental Index Setting. This section compares our method in this paper with the methods in [5] and [6]. We use the accuracy of the classroom teaching behavior recognition and the evaluation error for the comparison.

4.3. Analysis of Experimental Results. By analyzing the data in Figures 2 and 3 under the same experimental conditions, the accuracy of sample classroom teaching behavior recognition is analyzed using the methods of this paper, Zhao et al. [5], and Ya-jun et al. [6]. Among them, the accuracy of our proposed method is always higher than that of the other two methods. When the number of iterations is 80, the identification accuracy of our proposed method reaches the highest value, about 98%. When the number of iterations is 80, the highest accuracy of the method in [5] is about 91%. When the number of iterations is 40, the highest accuracy of the method in [6] is about 89%. In contrast, our proposed method has the highest accuracy in identifying sample classroom teaching behavior. This is because we use a convolutional neural network to recognize classroom teaching behavior recognition.

In order to further verify the effectiveness of our method, we compared the evaluation results of sample classroom teaching behaviors and conducted experimental analysis on the results. The evaluation error is shown in Figure 4.

By analyzing Figure 4, it can be seen that there is a certain gap in the evaluation error of the evaluation results of sample classroom teaching behavior by using the methods of this paper, Zhao et al. [5], and Ya-jun et al. [6]. When the number of iterations is 20, the error of our method on the evaluation of sample classroom teaching behavior is about 1.9%, the error of Zhao et al.'s [5] method on the evaluation of sample classroom teaching behavior is about 4.1%, and the

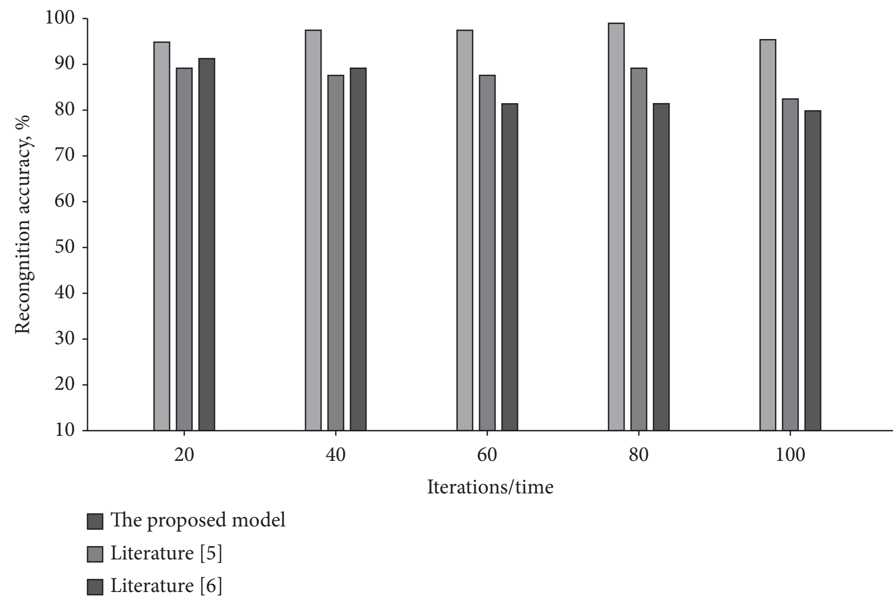

Figure 2: Precision analysis of classroom teaching behavior identification by different methods.

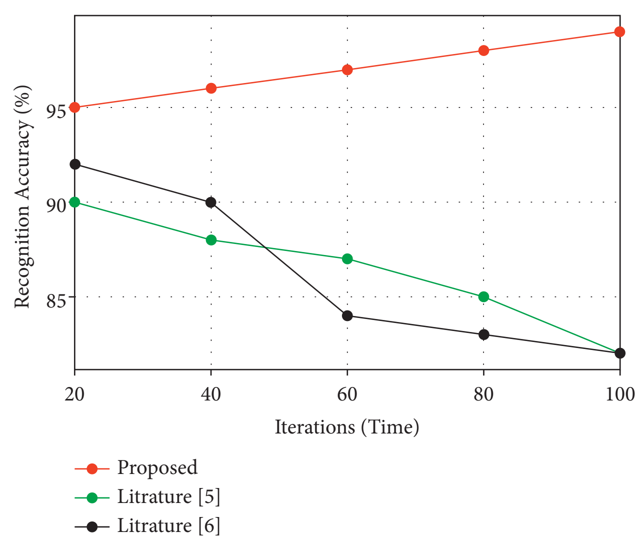

Figure 3: Precision analysis of our proposed method with respect to the state-of-the-art methods.

error of Ya-jun et al.'s [6] method on the evaluation of sample classroom teaching behavior is about 5.5%. When the number of iterations is 40, the error of our method on the evaluation of sample classroom teaching behavior is about 1.5%, the error of Zhao et al.'s [5] method on the evaluation of sample classroom teaching behavior is about 3.5%, and the error of Ya-jun et al.'s [6] method on the evaluation of sample classroom teaching behavior is about 5%. When the number of iterations is 60, the error of our method on the evaluation of sample classroom teaching behavior is about 1.2%, the error of Zhao et al.'s [5] method on the evaluation of sample classroom teaching behavior is about 5%, and the error of Ya-jun et al.'s [6] method on the evaluation of sample classroom teaching behavior is about 4.1%. Similarly, when the number of iterations is 100, the error of our method on the evaluation of sample classroom teaching behavior is about 1.8%, the error of Zhao et al.'s [5] method on the evaluation of sample classroom teaching behavior is about 3%, and the error of Ya-jun et al.'s [6] method on the evaluation of sample classroom teaching behavior is about 2.8%. In contrast, the error of the sample classroom teaching behavior evaluation of the proposed method is the lowest, which verifies the effectiveness of this method.

We also experiment with different dropout levels because dropout plays such an important role in the convergence time and performance of any DL-based model [16]. The impact of the dropout is seen in Figure 5. It can be observed that when dropout is not utilized, our model outperforms the identical model. This also confirms that our dropout is required for our proposed model to work optimally.

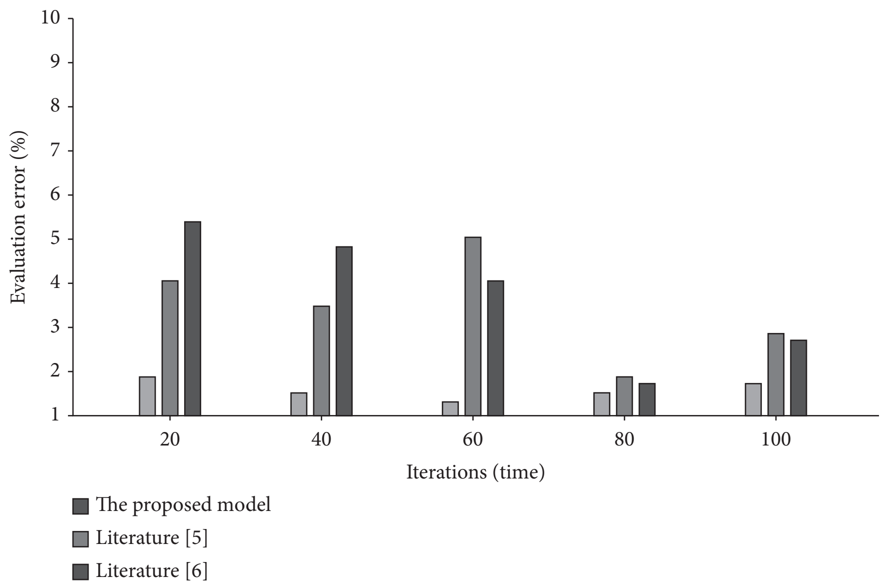

Figure 4: Error analysis of sample classroom teaching behavior evaluation by different methods.

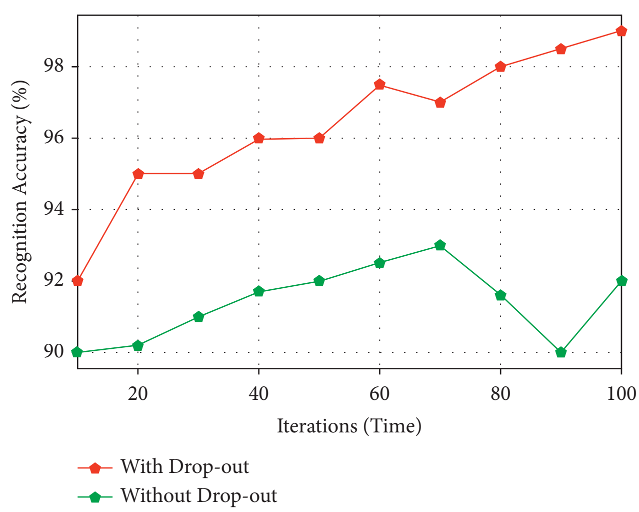

Figure 5: Precision analysis of classroom teaching behavior identification with respect to the dropout setting.

5. Conclusion

This paper studies classroom teaching behavior recognition and proposes a novel method based on the convolutional neural network (CNN). We first obtain the classroom teaching behavior characteristic data through the SVM linear separable initial, determine the relationship of the characteristic sample data in the hyperplane, obtain the heterogeneous support vector of the online learning behavior characteristic sample data in the SVM hyperplane, and complete the extraction of the characteristic data. With the help of the convolution, pooling, and fully connected layers, we recognize classroom teaching behavior. Then, through an analytic hierarchy process, we construct the confusion matrix to determine the weight of classroom teaching behavior indicators, verify their consistency, and complete the evaluation of classroom teaching behavior by calculating the membership of evaluation factors. The experimental results show that the identification and evaluation method of classroom teaching behavior in this paper can effectively improve classroom teaching behavior identification accuracy.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

Application of the WNN-Based SCG Optimization Algorithm for Predicting Soft Soil Foundation Engineering Settlement

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Settlement prediction in soft soil foundation engineering is a newer technique. Predicting soft soil settling has long been one of the most challenging techniques due to difficulties in soft soil engineering. To overcome these challenges, the wavelet neural network (WNN) is mostly used. So, after assessing its estimate performance, two elements, early parameter selection and system training techniques, are chosen to optimize the traditional WNN difficulties of readily convergence to the local infinitesimal point, low speed, and poor approximation performance. The number of hidden layer nodes is determined using a self-adaptive adjustment technique. The wavelet neural network (WNN) is coupled with the scaled conjugate gradient (SCG) to increase the feasibility and accuracy of the soft fundamental engineering settlement prediction model, and a better wavelet network for the soft ground engineering settlement prediction is suggested in this paper. Furthermore, we have proposed the technique of locating the early parameters based on autocorrelation. The settlement of three types of traditional soft foundation engineering, including metro tunnels, highways, and high-rise building foundations, has been predicted using our proposed model. The findings revealed that the model is superior to the backpropagation neural network and the standard WNN for solving problems of approximation performance. As a result, the model is acceptable for soft foundation engineering settlement prediction and has substantial project referential value.

1. Introduction

Prediction of soft soil settlement has always been one of the technical problems in soft soil engineering. As there are many factors affecting the settlement of soft foundations, how to predict the settlement of soft foundations correctly becomes a common problem for researchers in design and construction. To improve the accuracy, calculation and prediction based on measured data are a general method in engineering at present [1]. Commonly used deformation prediction methods based on measured data include statistical analysis, time series analysis, grey system theory, Kalman filter, and neural networks, but these have their limitations [2, 3]. Optimizing the model and improving the prediction accuracy are an important content of the deformation prediction model. According to the actual application research, a single theory or model is difficult to accurately predict the magnitude of deformation. The close combination and comprehensive comparison of multiple theoretical models is an effective way to study the prediction of deformation [3, 4]. By integrating the advantages of wavelet analysis with artificial neural networks, the wavelet neural network (WNN) has been swiftly established and has played a key role in deformation monitoring. On the other hand, as the economy has grown, communities have seen an increase in the number of high-rise structures. The settling of the building foundation must be checked and anticipated to assure its safety during the construction and operation phases. However, due to the difficulty of physical circumstances and the ambiguity of the causes driving settlement, using traditional certainty concepts to forecast settlement is extremely challenging. Although the inclusion of WNN simplifies the problem, it has several drawbacks in its current form.

The wavelet neural network (WNN) is a new exploration under this guiding ideology, which combines wavelet analysis and neural network successfully and thus provides a scientific theoretical basis and analysis tool for modern forecasting [5, 6]. There are many forms of WNN. Compact wavelet neural networks that use wavelet functions to replace the hidden layer functions of conventional neural networks seem common, but they display convergence to local minima, low speed, and poor approximation performance frequently, and some other shortcomings as well [6–9]. Accordingly, the present study proposes an optimized WNN built on the scaled conjugate gradient algorithm (SCG). Within the study, the settlement data of metro tunnels, highway soft foundations and roads, and high-rise buildings are taken as soft foundation engineering examples. Three neural networks, BP neural network, the traditional WNN based on backpropagation (BP algorithm), and WNN based on SCG algorithm, are compared and analyzed comprehensively. This article designed an optimization of WNN built on the SCG method to predict soft soil foundation engineering settlement under the complex geology settings to overcome issues mentioned above. The results show that the optimization model achieves a better performance and is more suitable than the other two networks for soft soil foundation engineering settlement prediction.

The following are the offerings of this research work:

(1) We investigate the soft soil foundation engineering settlement prediction and wavelet neural network. We explain the methodology that we have adopted during our proposed work and perform experiment for our three techniques, i.e., BP Neural Network, WNN-based BP Algorithm, and Improved Wavelet Neural Network.
(2) We compare the prediction accuracy obtained during the three techniques mentioned above.
(3) Our proposed work improves the stability and convergence accuracy of WNN. Hence, the initial parameter setting method can be linked with wavelet type, wavelet time-frequency parameters, and learning samples.
(4) From our proposed scheme, we concluded that SCG algorithm combined with the autocorrelation correction can determine the number of hidden layer nodes. Thus, an improved WNN can be derived successfully.

The rest of the research work consists of the following: Section 2 explains the related work, Section 3 illustrates material and methodology used during our proposed work, Section 4 deliberates our experimental work that we have performed during our work, and finally, the paper is concluded in Section 5.

2. Related Work

Soft soil is found all around the world. Its unique characteristics, i.e., high void ratio, high water content, high compressibility, low shear strength, low permeability, and unique structural characteristics, necessitate particular consideration in the study, construction, and maintenance of geotechnical structures built on them. Large-scale construction of high-speed transit systems, high-rise structures, and subterranean works for numerous urban centers built on such soils is a huge problem. Many researchers have attempted to overcome the issues that arise in the foundation of soft soils. The authors in [10] used a three-dimensional (3D) analytic approach to investigate the influence of pavement smoothness on the dynamic behavior of subsurface movement loads. The impact of unconventional and low-carbon additions on the long-term treatment of soils for building and paving materials is investigated. Data from three centrifuge tests during traffic loads are used to study the cyclic behavior of mud with a ground comprised of overcompacted soil at the top.

The researchers of [6] used a 3D dynamic finite-element analysis to estimate the permanent settling of a segment of the cross-river tunnel, allowing for the influence of primary stress rotation and verifications for test data. The disrupted state concept (DSC) model for normally consolidated clays was described in [11], which included the impacts of cracking, particle breaking, heating, softness, and hardening. The overconsolidation ratio on strength, militancy, and distortion is used to develop a novel disruption function. Consolidation theory, numerical computation, and curve fitting are three types of approaches for forecasting ground settlement. There have been several recent works on consolidation theory [12–14].

In a novel approach, the authors of [15] described the settlement of an inspired embankment on a soft basis based on a classic hyperbolic approach and used the system deformations features reflected in preloaded embankments to forecast the settlement during the later stage. In [16], the authors proposed a staged observational technique for predicting embankment settlement on soft ground with staged construction; they discovered that immediate settlement adds to the shift distance of the parallel lines during staged construction. The researchers in [17] used a genetic algorithm to optimize a BP neural network to forecast the summer electrical short-term load. Because of its high convergence rate and low memory use, the scaled conjugate gradient (SCG) method is used in NFC training. As a result, the authors of [18] trained a type-1 fuzzy system using a customized form of SCG. According to them, the improved SCG accelerates convergence in the steepest descent approach of fuzzy system training. As a consequence, the SCG appears to be a good candidate for NFC training for large-scale issues. Training NFC with SCG for large-scale issues, on the other hand, might take days or weeks on any personal computer. Training NFC with SCG for large-scale issues, on the other hand, might take days or weeks on any personal computer. An alternate method for reducing training time is to calculate the Hessian matrix using first-order gradients, as in conjugate gradient (CG) algorithms [19]. A transformation wavelet is a useful tool for data processing and time-frequency representation development. The wavelet theories are described thoroughly in [20, 21]. In the context of neural networks, the application of wavelet transform is not new. Previous research [22, 23] proposed a theoretical framework for neural feed-forward networks based on wavelets. The study of [24] has investigated the capacity to employ wavelet-based cross-pollination for an unknown real-time function. Because wavelets have a high compression capacity and have fewer coefficients, the results were achieved in this circumstance.

In [25], the authors offer a statistical model identification framework for using wavelet networks, which is studied over a wide range of topics, including architecture, initialization, variable selection, and model selection. Because of their capacity to extract varied information, wavelet-based techniques have been employed in numerous computer vision applications using Convolutional Neural Networks (CNN). Wavelet CNN texture classification [26], multiscale face superresolution [27], picture superresolution [28], and edge feature boosting [29] are only a few examples. In [30], a multilevel wavelet CNN model for picture restoration was presented. The researchers in [31] suggested a new layer that conducts wavelet-based convolution filtering and activation before returning to pixel space.

Similarly, [32] created a hybrid wavelet deep learning network based on the wavelets scattering transform [33]. This presented a basic classification that was subsequently enhanced [34]. In [35], the authors also suggest a wavelet for the segmentation of the brain tumors, which is strengthened by an evolutionary network design, and for this application, DWT is coupled with the neural network classification [36]. To lower the spatial resolution and expand the receptive field to dense pixel-specific prediction, encoder-decoder CNN architecture with encoder DWT and inverse decoder DWT was presented in [37]. In addition, a neural wavelet network for speech and noise separation was proposed in [38]. The researchers in [39] built WNN optimization based on the SCG algorithm to forecast the settling of the foundation of the structure under complex geological circumstances. The findings indicated that WNN optimization was optimal and that this had a positive effect compared to the BP neural network and the BP WNN. Inspired from the work of above scholars, this research work combines wavelet neural network (WNN) with optimized scaled conjugate gradient algorithm to successfully predict the soft soil foundation engineering settlement by performing numerous experiments.

3. Materials and Methodology

3.1. Materials Used during Our Research Work

3.1.1. Soft Soil Foundations. Soft soil foundation consists of soft soil with finer particles and organic soil with wider gaps, because its texture comprises mucky soil with silt and other highly compressible soils with clay components and silt components [40] in fine soil particles. The soft foundations of soil are mostly based on the changes in soil foundations produced by geographical circumstances, geological structures, and the soil conditions' features and qualities.

(1) Characteristics of Soft Soil Foundation. The major characteristics of soft soil include low water permeability and high water content, according to the basic attributes of soil. However, the water permeability is poor, and the shear strength is exceedingly low [41]. The shear foot brake and compression system with high compressibility or mucky soil generally exhibit considerable settlement after the external load is transmitted to the foundation section. As a result, constructions erected on soft soil foundations, such as buildings, roads, and bridges, have a significant inclination or settlement. It is straightforward to cause the injury and crack of the building, and therefore, the increase of the macrospore, which can cause the collapse of the building once it is serious. Therefore, the municipal construction units should actively analyze and study the soft soil foundation treatment and scientifically discover and take a look at the shear resistance and cargo resistance level of the soft soil foundation [42].

(2) The Impact of Soft Soil Foundation. The impact of soft soil foundation can be seen in Figure 1 and its major components are as follows:

(1) Poor bearing capacity: due to the high water content and tiny seepage of the soil conditions in soft soil foundations, the bearing strength of the foundation is fairly low, making settlement foundations extremely simple to produce, posing a severe danger to residents' travel quality [43].
(2) Large settlement: the significant settlement is one of the features of a soft soil foundation. The settling features of soft soil foundations will create additional difficulties for engineering building projects and pose a severe danger to the progress and quality of engineering projects.
(3) Strong compressibility: the soft soil ductility is strong, due to the macrospore structure depending on water content and soil quality [12]. During construction, the macrospore's soft soil layer is endangered, which prevents appropriate control measures from being taken and further impacts the efficiency and progress of the building and the stability of the base. The consequence is easy to dislocate the path and the subgrade of the city's engineering structure collapses.

3.1.2. Wavelet Neural Network. Wavelet Networks are a novel network type that brings together traditional Sigmoid Networks (NNs) with Wavelet Analysis (WA) [43]. The stretch factor, denoted by aj, and the panning element, denoted by bj, are two new parameters introduced by this technique. These new parameters replace the respective weights and thresholds of the neural network by using the wave element to replace neurons and establish a connection between the transforming and the neural networks through an approximation of wavelet decomposition [25]. The wavelet neural network contains three layers according to Figure 2: input layer, hidden layer, and layer output. During the forward propagation learning phase, the data from the input layer is processed and sent to the hidden layer. The data is subsequently processed in the output layer by a hidden layer. After that, at the backpropagation stage, the

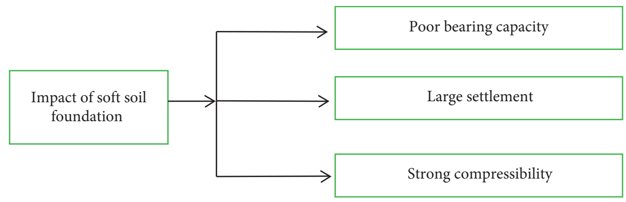

Figure 1: Impact of soft soil foundation.

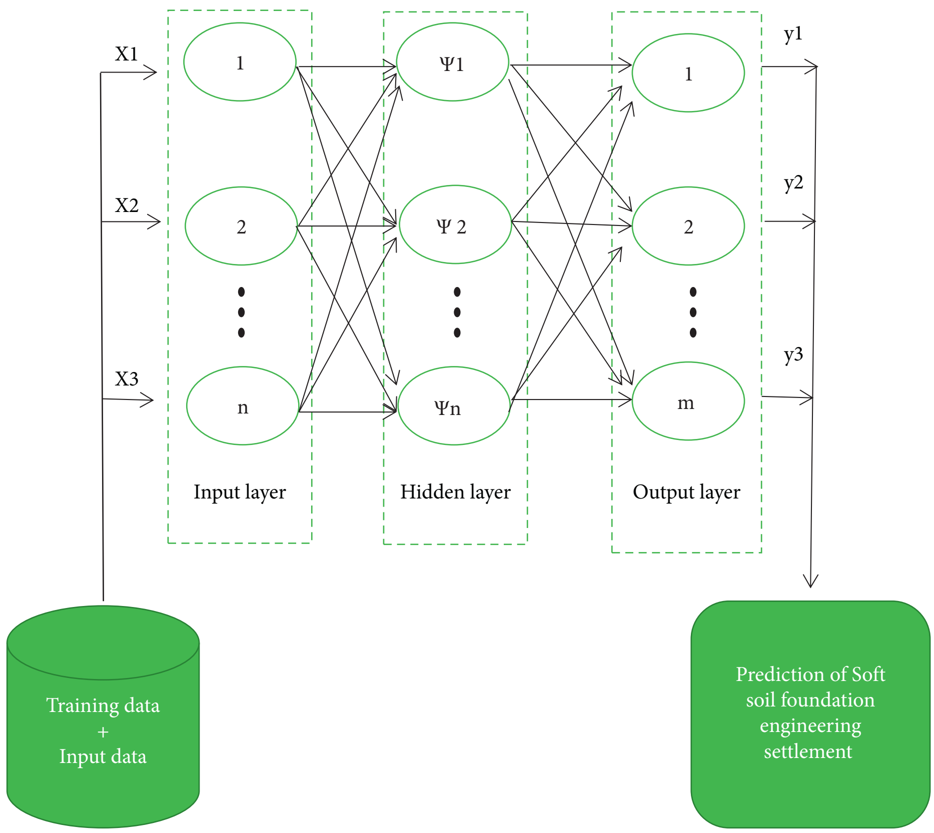

Figure 2: Wavelet neural network.

output layer determines the output value of each unit by computing the difference between the output value and the intended output values. Finally, the weight to modify each input layer and the hidden layer is the product of each receiving unit error value and transmission unit activation value [44, 45].

3.2. Methodology

3.2.1. Convergence Analysis. After considering the WNN's limitations, the main issue is poor convergence. When the wavelet-based neural network uses the BP neural network's initialization and training technique, there will be poor convergence difficulties and recommended improvements [7]. This is due to the differing activation functions of the hidden layer nodes. This article optimizes the initial parameter selection technique as well as the network training method based on this.

3.2.2. Optimization of the WNN

(1) Selection of Initial Values of Network Parameters. The initialization of network parameters has an impact on whether or not the network's subsequent learning converges and how quickly it converges. Currently, random values are used to create the initial parameters of WNNs, which significantly increases the number of learning times and even causes the network to fail to converge. The author suggested an autocorrelation correction initial parameter setting technique in [46], which links the initial parameter settings of WNN with wavelet types, wavelet time-frequency parameters, and learning samples. Excellent starting parameters may be obtained with a high degree of certainty using this approach, and the wavelet network's follow-up learning speed will be substantially increased. As a result, this article uses this approach to determine the initial values of network parameters, which will be discussed further in this article.

(2) Determination of the Network Structure. In this section, we discuss the structure of our proposed Wavelet Neural Network based on optimized scaled conjugate gradient algorithm for the prediction of soft soil foundation engineering settlement.

(1) Number of hidden layers: the researcher of [47] demonstrated that a three-layer neural network model can handle general function fitting and approximation issues. Because settlement prediction is a function fitting issue, a three-layer wavelet neural network will suffice.
(2) Number of hidden layer nodes: the number of hidden layer nodes directly influences the network's generalization ability and training time; therefore, it is crucial in the development of the neural network model. There is, however, no theoretical direction in this area. The primary approaches used in practical applications are testing or the use of empirical equations [48].

This study presents an adaptive technique based on empirical formulas for obtaining a higher number of hidden layer nodes. To begin, use equation (1) to find the number of hidden layer nodes and the maximum number of learning periods for the network. When the network reaches its maximum number of nodes, the number of hidden layer nodes will increase since it is still unable to fulfill the error criteria. Similarly, when the network does not meet the learning number specified, and the error criterion is fulfilled concurrently, the number of hidden layer nodes will decrease.

$$O = \sqrt{m+n} + 1. \tag{1}$$

Here, n is the number of input nodes, m is the number of output nodes, is the number of hidden layer nodes, and l is a constant between one and twenty.

3.2.3. Optimization of Learning Algorithm. Because the traditional BP network utilizes the steepest descent method, the primary drawback is that this slows down network convergence and is readily confined to the best local solution [41], too. For that reason, there were several optimization methods, among these; for its similarity in nature to the SDBP algorithm but with a higher convergence time, the connected gradient algorithm is frequently employed for tackling big optimization issues. For this reason, the SCG method [49] is used in this article for network training in the combined gradient algorithm. The following is the procedure of detailed application:

We take the error energy function as

$$E(\theta) = \frac{1}{2}\sum (f(x,\theta) - y)^2. \tag{2}$$

Here, x is the input value, y is the output value, and θ is a parameter.

For the objective function $E(\theta)$ of the wavelet neural network with P input samples, the gradient of the θ (i.e. w_{ki}, w_{jk}, a_k, b_k) is

$$\frac{E}{w_{ki}} = \sum_{p=1}^{P}\sum_{j=1}^{m}\left(f_j - y_j\right) w_{jk}\frac{\psi}{x\prime}x_i, \tag{3}$$

$$\frac{E}{w_{jk}} = \sum_{p=1}^{P}\left(f_j - y_j\right)\psi\left(\frac{\sum_{i=1}^{n} w_{ki}x_i - b_k}{a_k}\right), \tag{4}$$

$$\frac{E}{a_k} = \sum_{p=1}^{P}\sum_{j=1}^{m}\left(f_j - y_j\right) w_{jk}\frac{\psi}{a_k}, \tag{5}$$

$$\frac{E}{b_k} = \sum_{p=1}^{P}\sum_{j=1}^{m}\left(f_j - y_j\right) w_{jk}\frac{\psi}{b_k}. \tag{6}$$

If the Morlet wavelet function is used, namely, $\psi(t) = e^{(-t^2/2)}\cos(5t)$, then

$$x' = \sum_{i=1}^{n} w_{ki}x_i, t' = \frac{x' - b_k}{a_k}. \tag{7}$$

Thus, the network parameters in equations (3) to (6) are

$$\begin{aligned}
\frac{\psi}{a_k} &= \cos(5t')e^{\left(-t'^2/2\right)}\frac{t'^2}{a_k} + 5\sin(5t')e^{\left(-t'^2/2\right)}\frac{t'}{a_k},\\
\frac{\psi}{b_k} &= \cos(5t')e^{\left(-t'^2/2\right)}\frac{t'}{a_k} + 5\sin(5t')e^{\left(-t'^2/2\right)}\frac{1}{a_k},\\
\frac{\psi}{t'} &= -\cos(5t')e^{\left(-t'^2/2\right)}\frac{t'}{a_k} - 5\sin(5t')e^{\left(-t'^2/2\right)}\frac{1}{a_k}.
\end{aligned} \tag{8}$$

Substituting these into the SCG algorithm, the optimal θ can be solved.

In the formulas above, $f_j\,(j = 1, 2, \ldots, m)$ is the output of the network, ω_{ki} is the connection weight between the kth neuron in hidden layer and the ith neuron in input layer, ω_{jk} is the connection weight between the jth neuron in output layer and the kth neuron in the hidden layer, and a_k, b_k are the scale parameters and translation parameters of the wavelet basis function.

3.2.4. Optimized Construction of the WNN. Based on the foregoing research, the improved WNN model in this paper is constructed in the following steps:

Step 1: select an appropriate amount of training samples, define the training samples according to certain rules, and determine the number of input neurons and output neurons of the network.

Step 2: the learning algorithm of the network: SCG algorithm.

Step 3: set the network training period, target error, and other parameters.

Step 4: calculate the number of hidden layer nodes in the network by empirical formulas, make adaptive optimization adjustments, and rebuild the network structure.

Step 5: transfer function: the hidden layer to the output layer adopts the sigmoid function, and the input layer to the hidden layer adopts the Morlet wavelet function.

Step 6: select a set of weights randomly and use the weights optimized by autocorrelation correction method as the initial weights for network training. Reset the training parameters of the network and use the SCG algorithm to train and establish an improved WNN.

3.2.5. Settlement Prediction Model. Equation (9) is used for sample normalization to make full use of the sensitivity of the Sigmoid function and improve the convergence speed of training [50].

$$x^* = \frac{x - x_{\min}}{2\left(x_{\max} - x_{\min}\right)}. \tag{9}$$

Here, $x_{\max}$ and $x_{\min}$ are the maximum and minimum values of each group of input components, and x and x^* are the values before and after normalization of each group of input components.

Apply the improved WNN described above.

Sample training: first, the measured samples $\{x_i, i = 1, 2, \ldots, n\}$ are divided into $k\,(k \in N, k \leq n)$ groups, and each group has $m + 1\,(m = n - k)$ value. The first value is used as the input node value of the network, and the latter is used as the expected value of the output node. Next, the network connection weight is trained. Then, using the converged connection weight, $x_k, x_{k+1}, \ldots, x_{k+m-1}$ are used as the network input to calculate the predicted value x_{k+m}. At last, after removing x_k and adding $x_{k+m}, x_{k+1}, x_{k+2}, \ldots, x_{k+m}$ are set as the new input of the network to calculate the predicted value x_{k+m+1}, and so on to make further predictions.

3.2.6. Training Plan. The three neural networks used have the same structure and training samples, and the differences are shown in Table 1. The training sample is the cumulative settlement value. The average of 10 times prediction will be the result to reduce the randomness of the predicted value. The model is evaluated by the relative error of the prediction result and the model accuracy. The model accuracy is given by

$$\text{Model accuracy} = \sqrt{\frac{\sum |\textit{predicted}\ \text{value} - \text{measured value}|^2}{n-1}}. \tag{10}$$

Here, n is the number of predicted value.

Table 1 represents a comparison of three models such as BP Neural Network, which uses the SDBP Algorithm as a learning method, where Sigmoid is the function of hidden layer by randomly generating the initial parameter. While the SDBP Algorithm is used as the learning technique in the BP Wavelet Neural Network, the Morlet Wavelet function of the hidden layer is generated randomly. Similarly, our Improved Wavelet Neural uses SCG Algorithm as a learning model instead of the SDBP Algorithm. The initial parameter in the case of our Improved Wavelet Neural Network is generating by the autocorrelation correction method.

4. Experimental Work and Results

Many soft foundation projects have emerged in recent years as a result of the steady building of national fundamental projects. Soft foundation engineering settlement prediction has always been a challenging topic in engineering due to the intricacy of soft foundation deformation. As a result, three neural networks are used to forecast the settlement of three common soft foundation projects: metro tunnels, roads, and high-rise structures, to compare and assess the convergence of the optimization model in this study.

4.1. Settlement Prediction of the Metro Tunnel. The west extension of one city's metro tunnel is located in a soft flowing murky salty clay layer with high moisture content, high compressibility, high sensitivity, low strength, and deformability. It is a floodplain of the Yangtze River with a thick covering layer, deep bedrock, and poor geological condition. As to the tunnel, its surrounding area is at the peak of the development period, there are many construction sites, and the settlement of its structure is obvious. The experimental data are 20 periods of the measurement points, which settled significantly. The first 15 periods of data are used as training samples to predict the settlement of the next 5 periods. The first 15 periods of data are divided into 8 training samples. Each group has 8 values: the first 7 values are used as the input of the network node, and the latter is used as the expected value of the output node. The prediction results of the three models are shown in Tables 2–5.

Table 2 illustrates the relative error and accuracy of settlement prediction of Metro Tunnel using BP Neural Network with training times 3503. During BP Neural Network, we obtain an accuracy of 2.45 for the number of measurements 16, 17, 18, 19, and 20.

Table 3 explains the relative error and accuracy of settlement prediction of Metro Tunnel using WNN-based BP Algorithm with training times 931. During this algorithm, we obtain an accuracy of 1.32 for the number of measurements 16, 17, 18, 19, and 20.

Table 4 describes the relative error and accuracy of settlement prediction of Metro Tunnel using Improved Wavelet Neural Network, with training times 267. During Improved Wavelet Neural Network, the accuracy of 0.89 for the number of measurements 16, 17, 18, 19, and 20 can be obtained.

Table 5 shows the relative error and accuracy of settlement prediction of Metro Tunnel using all the three techniques, with training times 3503, 931, and 267, respectively. This reflects that the model accuracy obtained during BP Neural Network, which is 2.45, is greater than the WNN-based BP Algorithm and Improved WNN for the number of measurements 16, 17, 18, 19, and 20.

Table 1: Comparison of three models.

S. no.	Model	Learning method	Hidden layer function	Initial parameter
1	BP neural network	SDBP algorithm	Sigmoid function	Randomly generated
2	BP wavelet neural network	SDBP algorithm	Morlet wavelet function	Randomly generated
3	Improved wavelet neural network	SCG algorithm	Morlet wavelet function	Autocorrelation correction method

Table 2: Settlement prediction of the metro tunnel using the BP neural network.

S. no.	Measurement number	Training times	Relative error (%)
1	16		0.152
2	17		0.343
3	18	3503	0.164
4	19		0.109
5	20		0.278
Model accuracy		2.45	

Table 3: Settlement prediction of the metro tunnel using WNN-based BP algorithm.

S. no.	Measurement number	Training times	Relative error (%)
1	16		0.079
2	17		0.073
3	18	931	0.118
4	19		0.060
5	20		0.200
Model accuracy		1.32	

Table 4: Settlement prediction of the metro tunnel using the improved wavelet neural network.

S. no.	Measurement number	Training times	Relative error (%)
1	16		0.058
2	17		0.095
3	18	267	0.103
4	19		0.029
5	20		0.095
Model accuracy		0.89	

Table 5: Settlement prediction of the metro tunnel using all three techniques.

Measurement number	BP neural network		WNN-based BP algorithm		Improved wavelet neural network	
	Training times	Relative error (%)	Training times	Relative error (%)	Training times	Relative error (%)
16		0.152		0.079		0.058
17		0.343		0.073		0.095
18	3503	0.164	931	0.118	267	0.103
19		0.109		0.060		0.029
20		0.278		0.200		0.095
Model accuracy	2.45		1.32		0.89	

4.2. Settlement Prediction of the Highway Soft Soil Roadbed. Yangtze River Bridge, opened to traffic in 2001, is one of the national key construction projects during the ninth five-year plan period. Its lead is a soft soil foundation, and settlement monitoring points are laid out according to its sections. The 13 periods of monitoring data from a monitoring point on a certain section are selected for prediction experiment, among which the first 9 period's data are used as training samples to predict the settlement of the last 4 periods. The settlement date of the first 9 periods is divided into 4 training samples. Each group has 6 values: the first 5 values are used as the input of the network node, and the latter is used as the expected value of the output node. The three network models are used to predict respectively; the results are given in Tables 6–9.

Table 6 illustrates the relative error and accuracy of settlement prediction of soft soil roadbed of highway using BP Neural Network with training times 2589. During BP Neural Network, we obtain an accuracy of 6.10 for the number of measurements 10, 11, 12, and 13.

Table 6: Settlement prediction of the soft soil roadbed of the highway using the BP neural network.

S. no.	Measurement number	Training times	Relative error (%)
1	10	2589	0.216
2	11		0.123
3	12		0.206
4	13		0.172
Model accuracy		6.10	

Table 7: Settlement prediction of the soft soil roadbed of the highway using WNN-based BP algorithm.

S. no.	Measurement number	Training times	Relative error (%)
1	10	616	0.128
2	11		0.096
3	12		0.112
4	13		0.103
Model accuracy		3.65	

Table 8: Settlement prediction of the soft soil roadbed of the highway using the improved wavelet neural network.

S. no.	Measurement number	Training times	Relative error (%)
1	10	132	0.015
2	11		0.096
3	12		0.055
4	13		0.054
Model accuracy		1.82	

Table 7 describes the relative error and accuracy of settlement prediction of soft soil roadbed of highway using WNN-based BP Algorithm with training times 616. During this technique, we obtain an accuracy of 3.65 for the number of measurements 10, 11, 12, and 13.

Table 8 explains the relative error and accuracy of settlement prediction of soft soil roadbed of highway using Improved Wavelet Neural Network, with training times 132. During Improved Wavelet Neural Network, the accuracy of 1.82 for the number of measurements 10, 11, 12, and 13 can be obtained.

Table 9 shows the relative error and accuracy of settlement prediction of soft soil roadbed of highway using all the three techniques, with training times 2589, 616, and 132, respectively. This reflects that the model accuracy obtained during BP Neural Network is 6.10 for the number of measurements 10, 11, 12, and 13. This reflects that this accuracy is greater than the WNN-based BP Algorithm and Improved WNN.

4.3. Settlement Prediction of the Building Foundation. The 21 periods monitoring data of a high-rise building soft foundation are taken for analysis. The first 13 periods of data are used as training samples to predict the settlement of the last 8 periods of observation. Use the three network models to make predictions, and the results are listed in Tables 10–13.

Table 10 illustrates the relative error and accuracy of settlement prediction of building foundation using BP Neural Network with training times 3201. During BP Neural Network, we obtain accuracy of 0.43 for the number of measurements 14, 15, 16, 17, 18, 19, 21, and 21.

Table 11 describes the relative error and accuracy of settlement prediction of building foundation using WNN-based BP Algorithm with training times 1145. During this technique, we obtain an accuracy of 0.47 for the number of measurements 14, 15, 16, 17, 18, 19, 20, and 21.

Table 12 shows the relative error and accuracy of settlement prediction of building foundation using Improved Wavelet Neural Network, with training times 254. During Improved Wavelet Neural Network, the accuracy of 0.35 for the number of measurements 14, 15, 16, 17, 18, 19, 20, and 21 can be obtained.

Table 13 shows the relative error and accuracy of settlement prediction of building foundation using all the three techniques, with training times 3201, 1145, and 254, respectively. This reflects that the model accuracy obtained during WNN-based BP Algorithm is 0.47 for the number of measurements 14, 15, 16, 17, 18, 19, 20, and 21. This reflects that this accuracy is greater than the rest of the two techniques.

Figures 3–5 show a comparison of the three techniques, where the mean relative error and maximum absolute error of the prediction results obtained using the BP neural network model are larger than those obtained using the WNN-based BP Algorithm. It demonstrates that the WNN-based BP Algorithm's generalization (prediction) capacity outperforms the BP neural network model. The forecast findings from the Improved WNN approach are larger than the measured settlement values, which is consistent with the actual engineering experience. When these two approaches are compared, the prediction power of the WNN-based BP Algorithm is superior to that of the Improved WNN method.

Table 9: Settlement prediction of the soft soil roadbed of the highway using all three techniques.

Measurement number	BP neural network		WNN based on BP algorithm		Improved wavelet neural network	
	Training times	Relative error (%)	Training times	Relative error (%)	Training times	Relative error (%)
10	2589	0.216	616	0.128	132	0.015
11		0.123		0.096		0.096
12		0.206		0.112		0.055
13		0.172		0.103		0.054
Model accuracy	6.10		3.65		1.82	

Table 10: Settlement prediction of the building foundation using the BP neural network.

S. no.	Measurement number	Training times	Relative error (%)
1	14	3201	0.096
2	15		0.018
3	16		0.048
4	17		0.011
5	18		0.012
6	19		0.014
7	20		0.061
8	21		0.035
Model accuracy		0.43	

Table 11: Settlement prediction of the building foundation using WNN-based BP algorithm.

S. no.	Measurement number	Training times	Relative error (%)
1	14	1145	0.060
2	15		0.056
3	16		0.070
4	17		0.037
5	18		0.009
6	19		0.001
7	20		0.031
8	21		0.088
Model accuracy		0.47	

Table 12: Settlement prediction of the building foundation using the improved wavelet neural network.

S. no.	Measurement number	Training times	Relative error (%)
1	14	254	0.025
2	15		0.043
3	16		0.053
4	17		0.024
5	18		0.029
6	19		0.014
7	20		0.010
8	21		0.071
Model accuracy		0.35	

The WNN outperforms the BP neural network in terms of prediction accuracy and convergence speed and has excellent adaptive prediction capabilities when compared to the WNN based on the SDBP algorithm, according to settlement prediction findings for three types of soft foundation engineering. As a result, the improved WNN based on the SCG algorithm greatly increases prediction accuracy and convergence speed.

Table 13: Settlement prediction of the building foundation using all three techniques.

Measurement number	BP neural network		WNN-based BP algorithm		Improved wavelet neural network	
	Training times	Relative error (%)	Training times	Relative error (%)	Training times	Relative error (%)
14	3201	0.096	1145	0.060	254	0.025
15		0.018		0.056		0.043
16		0.048		0.070		0.053
17		0.011		0.037		0.024
18		0.012		0.009		0.029
19		0.014		0.001		0.014
20		0.061		0.031		0.010
21		0.035		0.088		0.071
Model accuracy	0.43		0.47		0.35	

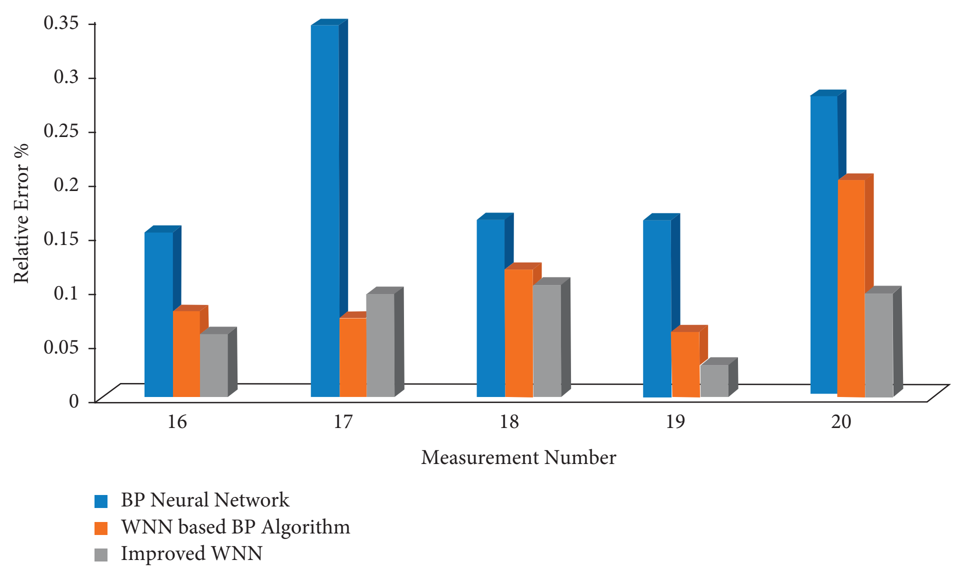

Figure 3: Settlement prediction of the metro tunnel.

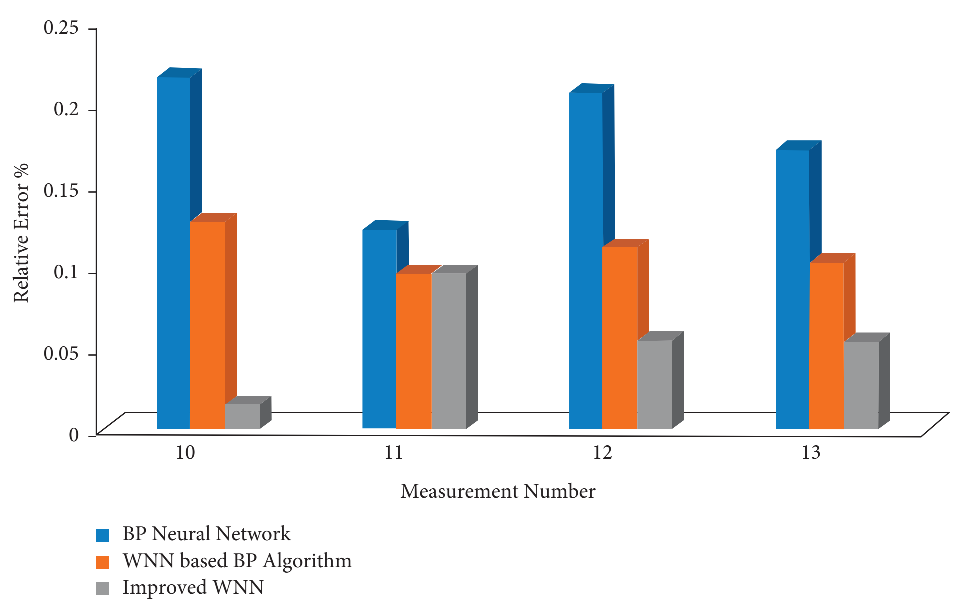

Figure 4: Settlement prediction of the soft soil roadbed of the highway.

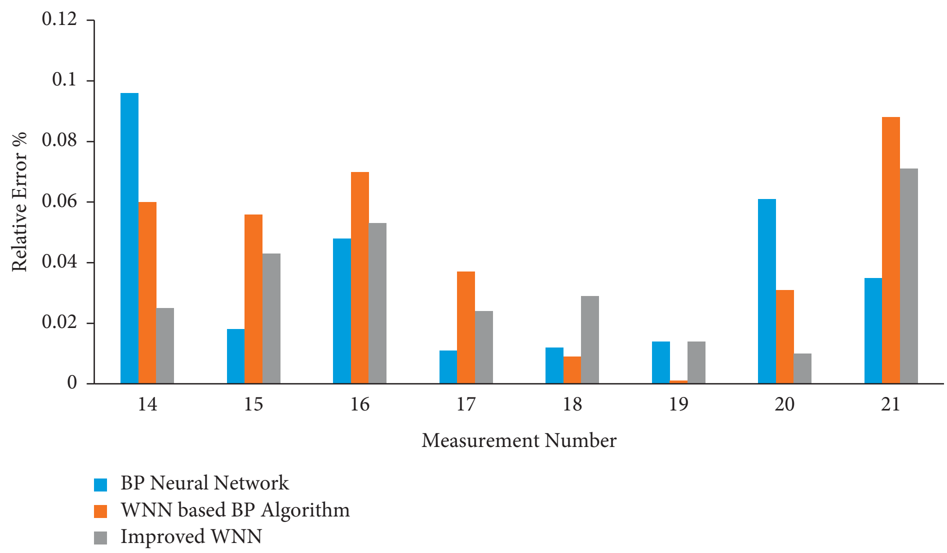

Figure 5: Settlement prediction of the building foundation.

5. Conclusion

Aiming at the convergence defects in the application of traditional settlement prediction models, this paper optimizes the WNN based on the traditional BP algorithm and applies it to soft foundation engineering. Here, we have introduced BP Neural Network and Improved Wavelet Neural Network in the soft ground foundation engineering forecast based on the basic concept of the wavelet neural network. The neural wavelet network method has been enhanced, and the scale conjugate gradient technique has been updated to maximize the excellent value neural wavelet network approach. The enhanced wavelet neural network settlement model is constructed, and settlements are predicted based on the conventional BP technique. The improved wavelet neural network model based on the classic BP method has greater prediction accuracy, and the soft soil settling has a good prediction effect with a specified reference value, according to the comparison of calculation accuracy evaluation indexes.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Guihua Li and Chenyu Han designed the study, analyzed the data, and wrote the manuscript. Hong Mei and Shuai Chen analyzed the data and contributed to writing the manuscript.

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Research Article

An Action Recognition Method for Volleyball Players Using Deep Learning

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This paper investigates the extraction of volleyball players' skeleton information and provides a deep learning-based solution for recognizing the players' actions. For this purpose, the convolutional neural network-based approach for recognizing volleyball players' actions is used. The Lie group skeleton has a large data dimension since it is used to represent the features retrieved from the model. The convolutional neural network is used for feature learning and classification in order to process high-dimensional data, minimize the complexity of the recognition process, and speed up the calculation. This paper uses the Lie group skeleton representation model to extract the geometric feature of the skeleton information in the feature extraction stage and the geometric transformation (rotation and translation) between different limbs to represent the volleyball players' movements in the feature representation stage. The approach is evaluated using the datasets Florence3D actions, MSR action pairs, and UTKinect action. The average recognition rate of our method is 93.00%, which is higher than that of the existing literature with high attention and reflects better accuracy and robustness.

1. Introduction

Volleyball players' action recognition has obtained a lot of attention in recent years, thanks to advances in computer vision, artificial intelligence, and pattern recognition. Virtual reality, medical rehabilitation, game creation, video surveillance, multimedia video retrieval, and other disciplines have all benefited from this new field of research. Early studies on volleyball player action identification relied mostly on the standard RGB colour video. Feature representation based on optical flow and motion information, spatiotemporal interest points, descriptive feature representation, and static feature representation based on shape are the most common ways. There are a number of things to consider, including the volleyball players' high degree of freedom, background confusion, camera movement and zooming, lighting changes, and video noise. Volleyball players' action recognition based on the classic RGB colour video is no longer a viable option. With the emergence of depth sensors such as Microsoft Kinect and ASUS XTION, the way of obtaining motion information has significantly improved. Using Kinect to rapidly and reliably extract bone information and depth information of human movements not only contains more volleyball players' motion information but also helps to overcome obstacles such as light, body temperature, and body temperature change. External environmental factors influence the changes in volleyball players' body shapes. Researchers currently employ angle change, joint position change, and the relative geometric relationship between the limbs of the volleyball players to depict the activity of volleyball players based on the bone information of the players.

For the development of volleyball players' action recognition, machine learning algorithm is a popular approach for action recognition. Algorithms such as support vector machine (SVM), boosting, and other similar algorithms are profoundly used nowadays. With the increasing convenience of data acquisition, deep learning algorithms began to shine. Combined with the strong feature learning ability of deep learning, the application of deep learning in volleyball players' action recognition greatly improves the recognition effect. In human interaction, understanding a person's action or behavior is an important aid to understand each other's intention, and people often spend a lot of time and energy to observe and explain others' behavior. Today, with the rapid development of economy and science and technology, people want to let machines understand human behavior, so as to carry out human-computer interaction more naturally and make machines bring better comfort to human beings. The purpose of action recognition of volleyball players is to let the machine automatically analyze the actions of volleyball players from their moveable data. The authors used the motion perception experiment [1] to sense the changes of the joint position and motion of the experimenter. The experimental results show that human vision not only detects the direction of motion but also detects different types of limb motion patterns, including the recognition of activity and speed of different motion patterns. The experiment is also considered as a pioneer in the field of volleyball players' behavior recognition. Zatsiorsky et al. [2] regarded volleyball players as a hinge system connected by joint points and then defined their actions as a continuous time transformation of limbs in space. This research laid the foundation for the development of action recognition of volleyball players based on skeletal limbs. With the advent and application of Kinect and other depth sensors, the authors carried out pioneering work to estimate the joint position of volleyball players from the depth map [3], which promoted the development of research on action recognition of volleyball players based on bone joints. In the field of computer vision, researchers define a volleyball player's skeleton as a schematic model composed of the head, trunk, and limbs. At present, two kinds of volleyball player's schematic models are widely used by the researchers, which are shown in Figure 1.

According to Turaga et al. [4], the behavior recognition of volleyball players is mainly action recognition. Volleyball players' action recognition mainly includes two stages of feature extraction and feature classification. In case of feature extraction, the early volleyball players' action recognition based on the RGB colour video mainly used manual extraction of action features, such as HOG/HOF features, HOG3d features, and SURF features [5]. This feature extraction method is more laborious and mainly depends on the experience of researchers, with limited development space. With the emergence of Kinect, researchers began to use the joint angle, joint position, and other key parts of volleyball players as the movement characteristics. In recent years, the feature extraction method based on the 3D relative geometric relationship between limbs has been proposed. The advantage of this method is that it can better overcome the problems of similarity between movements and intra-class difference. Feature classification is the process of judging different actions and featured data. The classical classifiers include the support vector machine (SVM) [6–8], hidden Markov model (HMM) [9, 10], and Bayesian networks (BNs) [11, 12]. In [13], the authors proposed deep belief networks (DBNs), which promoted the development of deep learning in academia and industry. As an extension of machine learning, deep learning has achieved great success in the field of image recognition, and it was gradually introduced into the field of dynamic video behavior analysis. The advantage of deep learning lies in deep feature learning for massive data, strong nonlinear fitting ability, and high-dimensional data processing ability, which has broad applications in feature extraction and classification. At present, there are deep learning shadows in the fields of action recognition, speech recognition, speech emotion recognition, and text emotion recognition.

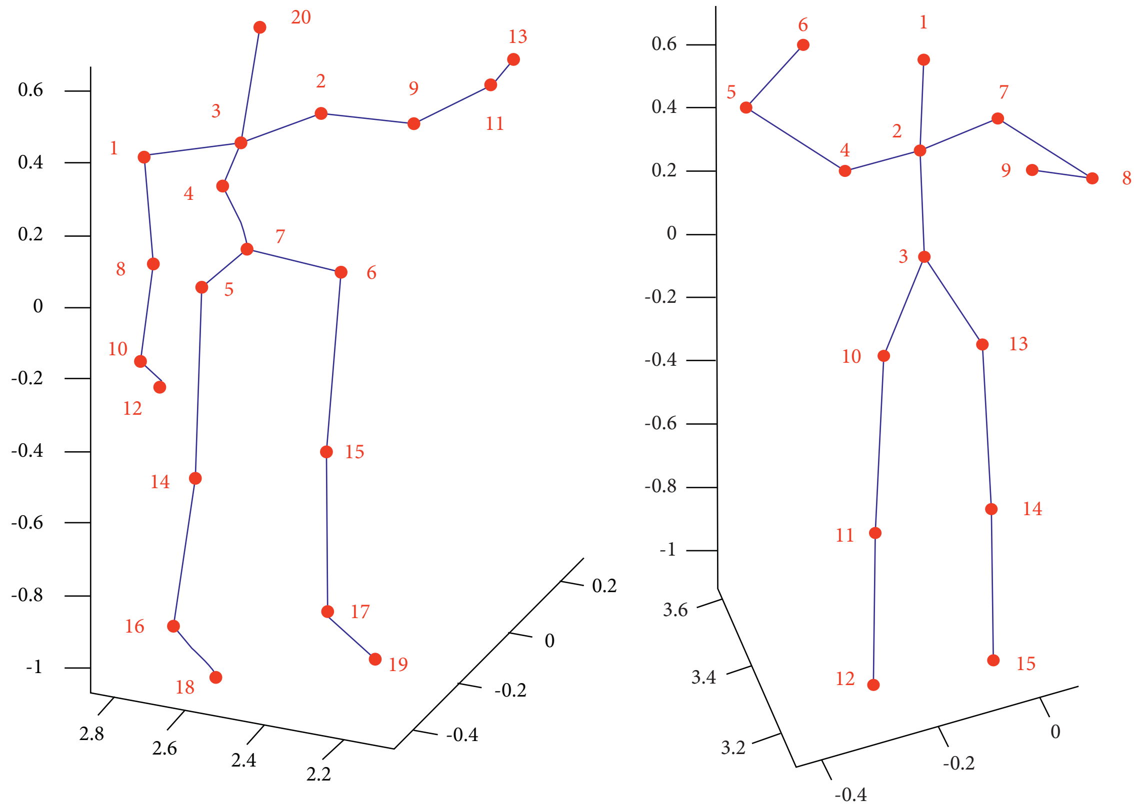
The rest of the paper is organized as follows. In Section 2, related work is discussed. In Section 3, the proposed action recognition method of volleyball players using a deep learning approach is discussed. In Section 4, experimental results and analysis are provided. Finally, the paper is concluded in Section 4.

2. Related Work

In this section, we provide the related work. First, the existing technology used for volleyball players' action recognition is discussed in Section 2.1. Next, the volleyball players' sports information acquisition technology is discussed in Section 2.2. Finally, the acquisition of bone information of the players is discussed in Section 2.3.

2.1. Technology for Volleyball Players' Action Recognition. In human communication, the actions of volleyball players, similar to their language, play an important role in conveying the information. The research of volleyball players' action recognition is often carried out in a modular way, that is, action data acquisition, action feature extraction, and feature classification. At present, the popular classic data acquisition methods are Kinect somatosensory technology and motion capture technology [14–19]. The methods of action feature extraction are mostly based on data sources, mainly including (1) feature extraction method based on the RGB colour image and depth image, which mainly extracts the spatial features of volleyball players' movement and (2) feature extraction method based on bone information, which mainly extracts the position coordinates of bones and joints, spatiotemporal changes, and limb angle, respectively. Common methods include spatiotemporal points of interest (STIPs), shape context, 3D joint point histogram (HOJ3D), and nonlinear 3D geometric relationship between limbs. Feature classification is the process of judging different features as specific actions. At present, the more popular classification methods are the support vector machine (SVM), hidden Markov model (HMM), random forest, and deep learning models, such as CNNs and DBNs.

In this paper, the proposed framework of volleyball players' action recognition method based on deep learning is shown in Figure 2. In the data acquisition stage, because Kinect is easy to extract volleyball players' bone information, this paper uses Kinect somatosensory technology for data acquisition. In the feature extraction stage, the Lie group skeleton representation model is used to extract the geometric features of the skeleton information and uses the geometric transformation (rotation and translation) between different limbs to represent the volleyball players'



(a) (b)

FIGURE 1: Volleyball player's model for different joint points. (a) 20 joints. (b) 15 joints.

movements. For feature classification, convolutional neural networks (CNNs) in the deep learning model are used for feature learning and classification.

2.2. Volleyball Players' Sports Information Acquisition Technology. For volleyball players' action data acquisition, obtaining appropriate action data will greatly promote the effect of action recognition. At present, the main data sources of volleyball players' actions include RGB-D video data, portable sensor data, depth information of volleyball players' actions, and bone information of volleyball players' actions, among which the open databases based on video data include KTH [20, 21], Weizmann [22], UCF sports [23], UCF101 [24], daily living [25], and YouTube [26]. Public databases based on depth information and bone information include MSR action 3D, MSR action pairs [27], NTU RGB + D [28], UTKinect action [29], and G3D gaming [29]. This paper mainly extracts bone information for volleyball players' action recognition.

2.3. Acquisition of Bone Information of Volleyball Players. The data acquisition of volleyball players' bone information is the key step for the players' movement analysis, which is of great value to analyze the changes in their posture and obtain movement information. Kinect's powerful function is its ability of bone tracking. Within the time delay range allowed by the system, it can quickly build the players' limbs according to their bone joints. There are two states of the skeleton: (1) when the skeleton is at rest at a certain time, it is a volleyball player's posture; (2) when the joints or limbs in the bone are in the state of motion in space, they appear as the actions or behaviors of the players.

3. Action Recognition Method of Volleyball Players Based on Deep Learning

Feature classification is one of the key steps of action recognition for volleyball players. The design of the classifier will directly affect the results of action recognition. This paper uses the convolutional neural network to learn and classify the action features. The biggest disadvantage of Li Qun's skeleton representation model is that when it represents the volleyball players' bones, it calculates the three-dimensional geometric relationship of each frame of bones and limbs and then superimposes the three-dimensional geometric relationship between the bones and limbs of the whole action sequence. This results in a relatively high feature dimension. Combined with the high-dimensional data processing ability and feature learning ability of deep learning, this section uses the convolutional neural network to classify the action features. It can reduce the complexity of data processing and save the cost of calculation. Moreover, it can get better effect of action recognition.

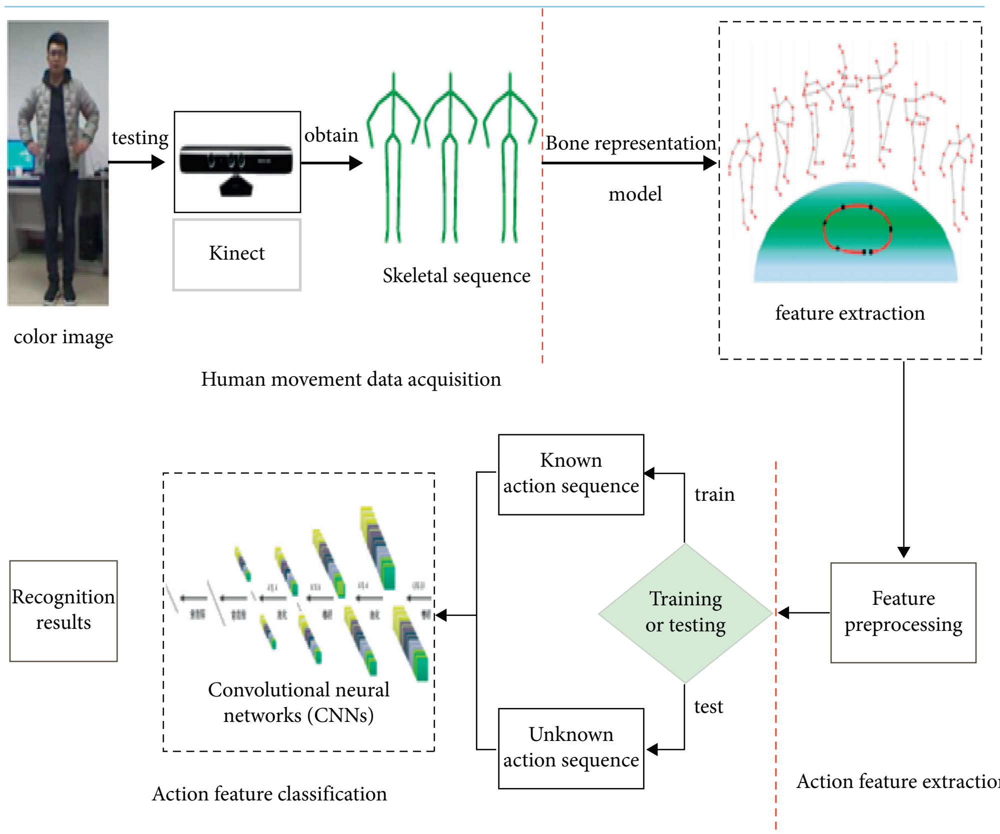


FIGURE 2: Action recognition of volleyball players using deep learning.

3.1. Convolutional Neural Network. The characteristics of the convolutional neural network (CNN) lie in local area perception, weight sharing, and temporal or spatial sampling. These characteristics make it possible to use fewer training parameters when using the CNN for data training. The CNN model reduces the complexity of the network, improves the calculation speed and generalization ability, makes the model invariant to translation, distortion, and scaling to a certain extent, and makes the model robust and fault-tolerant.

In the CNN, multiple feature maps constitute the convolutional layer, and multiple neurons constitute the feature map. Each neuron is locally connected with the feature map of the upper layer through the convolution kernel. In the structure of the CNN, the deeper the depth, the more the number of feature maps, the larger the feature space that the network can represent, and the stronger the learning ability. However, the depth and additional number of feature maps lead to overfitting. Convolution kernel is a weight matrix, which is used to extract features automatically according to the network model. The convolutional layer of the CNN extracts different features by checking the input data. In the first convolutional layer, some low-level features are often extracted, such as edge, line, and contour features, which can be used as the edge detector. The more advance the convolutional layer is, the more advance the feature extraction will be. After convolution, the size of the feature graph is calculated as follows.

Let the size of the input feature graph be $m\times n$, the convolution kernel be $k\times k$, and the sliding step of the convolution kernel be s; the size will be calculated as follows:

$$\left(\frac{(m-k)}{s}+1\right)\times\left(\frac{(n-k)}{s}+1\right). \tag{1}$$

In the convolution process, the expressions of the input and output are

$$y_j = f\sum_i w_{ij} * x_i + b_j. \tag{2}$$

In this equation, f is the activation function, which is used to change the input signal into the output signal. The commonly used activation functions are the sigmoid function, tanh function, ReLU function, radial basis function, and so on. w_{ij} is the transform weight, and b_j is the bias parameter. The convolution process is to slide the convolution kernel on the input matrix, multiply the corresponding weight of the convolution kernel by the data at the corresponding position of the input matrix, and add the results to get the final convolution result. The specific process is shown in Figure 3. In Figure 4, the size of the input feature map of the input layer is 4×5, the size of the convolution kernel is 2×2, and the sliding step is set as 1. At the beginning of sliding, the neurons (the range of the input blue box) in the feature map convolute with the convolution kernel to get the value of the output layer (blue box neurons).

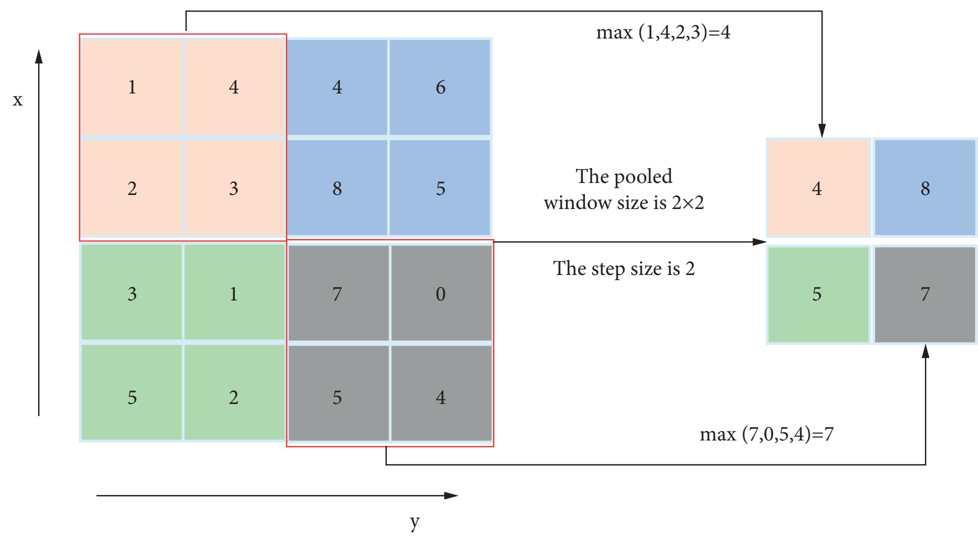


FIGURE 3: CNNs' convolution process.

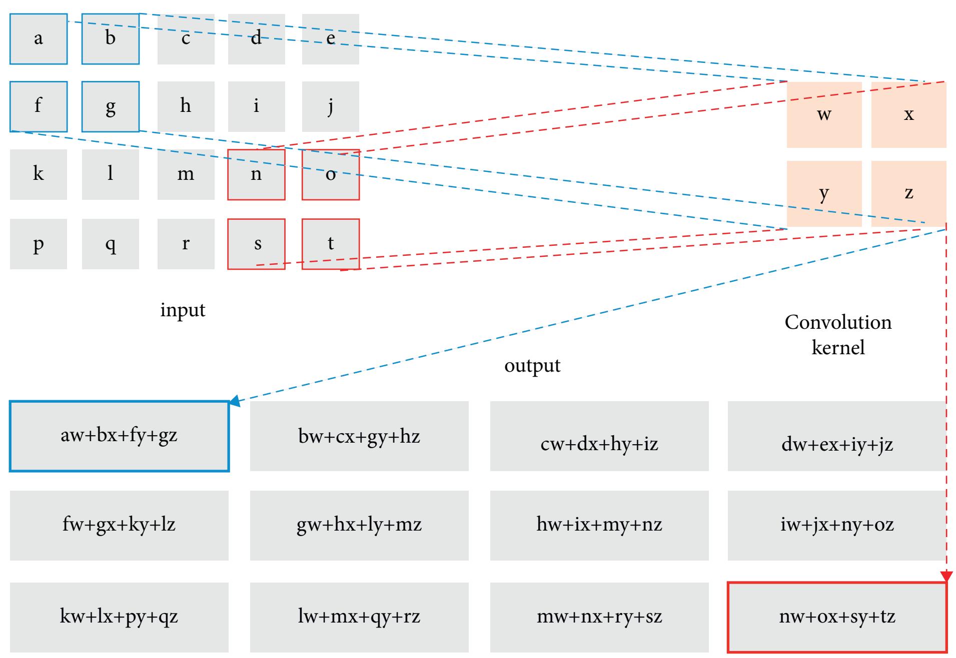


FIGURE 4: Pooling process of CNNs.

Similarly, when sliding to the red box area of the input layer, the neurons in this area convolute with the convolution kernel to get the value of red box neurons of the output layer. Finally, after convolution, the size of the input layer feature map becomes smaller, i.e., 3×4.

Combined with the fact that the data dimension of the action features extracted in this paper is high and with reference to the CNN model in [17], the basic structure of the CNN model proposed in this paper is shown in Figure 5. In the first layer, i.e., convolutional layer, a group of convolution checks with the size of 13×13 are used to convolute the input features. Here, the number of feature maps is set to 46. The second layer is the pooling layer, which selects the max pooling method, and the pooling core size is 4×4. This layer is used to reduce the feature dimension and ensure the same number of feature graphs as the previous layer. The third layer is the second convolutional layer of the model, the convolution kernel size is set to 8×8, and the number of characteristic graphs is 78. The fourth layer is the pooling layer. The size of the pooling core is set to 4×4, and the pooling mode is set as maximum pooling. After the previous convolution and pooling operations, the feature dimension is greatly reduced. At this stage, using the full connection layer, the local features are connected into 128-dimensional global feature vectors. The sixth layer is the output layer. At this layer, the number of neurons is the same as the number of action categories, which is used for the final classification. To avoid overfitting during training, due to the large amount

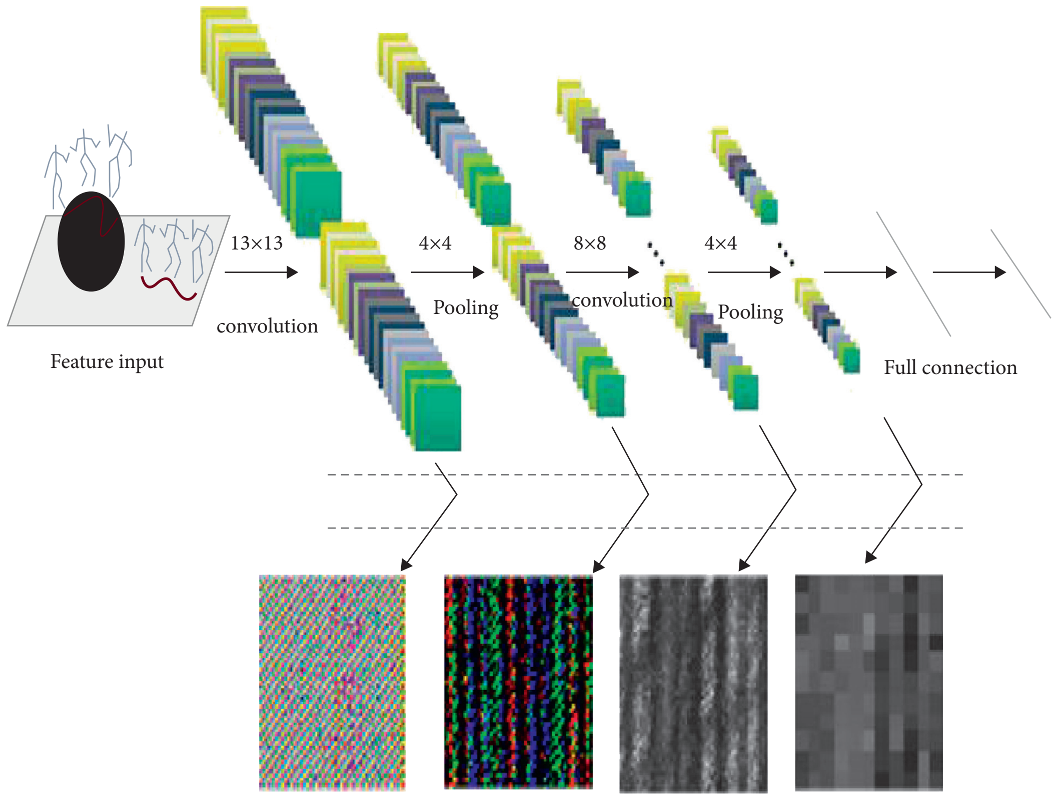


Figure 5: The convolutional neural network model of this paper.

of data, this section introduces weight attenuation in the loss function, i.e., L2 regularization, whose coefficient λ is 0.008. At the same time, when the gradient decreases, the momentum coefficient is introduced to accelerate the convergence speed, and its value is set to 0.9. During the experiment, the learning rate of the network is 0.0001.

In this paper, experiments are carried out on the open database Florence3D action. The size and quantity of each layer's feature map after its input and convolution and pooling operations are shown in Table 1.

4. Experimental Results and Analysis

Based on the volleyball players' action feature extraction and classification, this section verifies the accuracy of the proposed recognition method using open database Florence3D. The experimental results on three databases show that the proposed method can achieve ideal action recognition effect on public databases. It should be emphasized that this method has strong adaptability to the transplantation of the database. In other words, when the model is trained on one database, it can easily be transplanted to another database for experiments. There is no need to redebug the network parameters such as the number of network layers, the number of characteristic graphs, the size of the convolution core, and the size of the pooling core.

4.1. Experimental Analysis on the Florence3D Action Database. Firstly, the action sequence in the Florence3D action database is represented by the Lie group skeleton model for feature extraction. After feature preprocessing, the feature matrix is obtained. Out of the 215 action sequences in the database, 115 action sequences are selected as the training set, and the remaining 100 action sequences are selected as the test set, according to the setting idea of the training set and test set in [14]. The convolutional neural network proposed in this paper is used for feature recognition and classification. The recognition rate changes with the number of iterations, as shown in Figure 6. The average recognition rate of the proposed method is 93.00%. It can be seen from the analysis in Figure 6 that, with the increase of iteration times, the average recognition rate of database actions gradually tends to be stable, indicating that the network training is good. The experimental results in the Florence3D action database are shown in Table 2. According to the comparative experimental results, it is not difficult to see that this method has achieved good recognition results.

From the analysis of Table 2, it can be seen that the action recognition method of volleyball players in this paper can achieve better action recognition effect. Compared with some other popular action recognition methods, the effect of this paper is better. In particular, the average recognition rate of this method is 11% higher than that of L. Seidenari et al. [27], R. Vemulapalli [30], and others, which used the method of Li group skeleton representation and support vector machine (SVM) to recognize volleyball players' movements. Compared with the existing methods, this paper not only achieves better recognition effect but also consumes less time in the whole training time. The SVM does not reduce the dimension of high-dimensional data,

Table 1: The data format changes after convolution and pooling.

Database input	Convolution (13 × 13)	Pooling (4 × 4)	Convolution (8 × 8)	Pooling (4 × 4)	Fully connected	Fully connected
Florence3D action: (@180 × 180)	46@168 × 168	46@42 × 42	78@35 × 35	78@9 × 9	128@1 × 1	9
MSR action pairs: (3@ 260 × 260)	46@248 × 248	46@62 × 62	78@55 × 55	78@14 × 14	128@1 × 1	12
UTKinect action: (3@ 208 × 208)	46@196 × 196	46@49 × 49	78@42 × 42	78@11 × 11	128@1 × 1	10

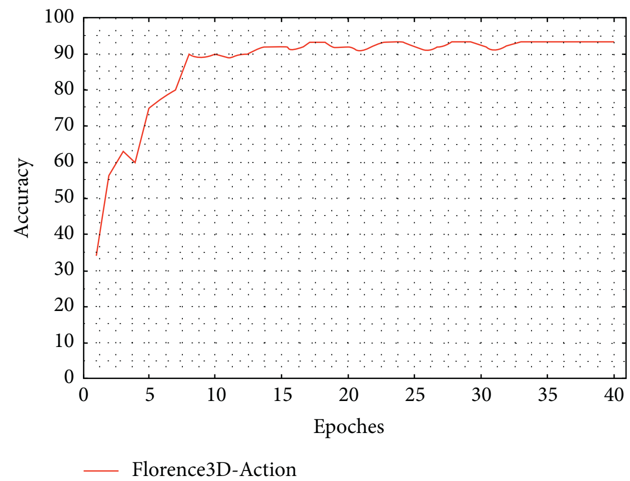


Figure 6: Broken line graph of recognition rate variation with iteration times.

Table 2: Comparison of the recognition effect of different volleyball players' action recognition methods on the Florence3D action database.

Action recognition method of volleyball players	Average recognition rate on the Florence3D action database (%)
L. Seidenari [26]	82.00
M. Devanne [28]	87.04
R. Anirudh [27]	89.67
R. Vemulapalli [29]	90.88
Method of this paper	93.00

but the CNN used in this paper can effectively process high-dimensional data, reduce the data complexity, and save the calculation cost. At the same time, the CNN has excellent feature learning ability, which is conducive to feature learning and classification.

When using the convolutional neural network for feature learning and classification, it is difficult to select the appropriate number of feature graphs. If the number of feature graphs is set too small, some features that are beneficial to network learning may be ignored. If the number of feature graphs is set to a high value, it will increase the network training parameters and training time, which is not conducive to the learning of the network model. In this paper, the experiments are carried out on different numbers of feature maps. For example, Table 3 shows the average recognition results of the three cases. It can be seen from the table that, for the CNN used in this paper, when the number of feature maps of the first convolutional layer is 46 and the number of feature maps of the second convolutional layer is 78, it can achieve a better recognition effect.

In the process of network training, the selection of network model parameters will greatly affect the effectiveness of the model, for example, the selection of key parameters such as the weight between the input layer feature map and the output layer feature map and bias parameters, which will produce different recognition results. In this paper, in order to achieve a satisfactory recognition effect, several experiments were carried out by selecting different parameter combinations (mainly including the size of the convolution kernel in different convolutional layers). These experiments took into account the actual situation of the high dimension of action-featured data extracted in this paper and also took the CNN model as a reference. The recognition results of several representative key model parameters are shown in Table 4.

Table 3: Influence of different numbers of feature maps on the recognition effect.

	Combination 1	Combination 2	Combination 3
Number of characteristic graphs Average recognition rate	The first layer is 40 The second convolutional layer is 60	The first layer is 46 The second convolutional layer is 78	The first layer is 60 The second convolutional layer is 90
Florence3D action (%)	91.00	92.00	93.00

Table 4: Influence of different convolution kernel sizes on the recognition effect.

	Combination 1	Combination 2	Combination 3	Combination 4
Convolution kernel size Average recognition rate	C1: 9×9 C2: 7×7	C1: 11×11 C2: 7×7	C1: 13×13 C2: 8×8	C1: 15×15 C2: 8×8
Florence3D action (%)	91.00	92.00	93.00	92.00

Note. C1 is the first convolution, and C2 is the second convolution.

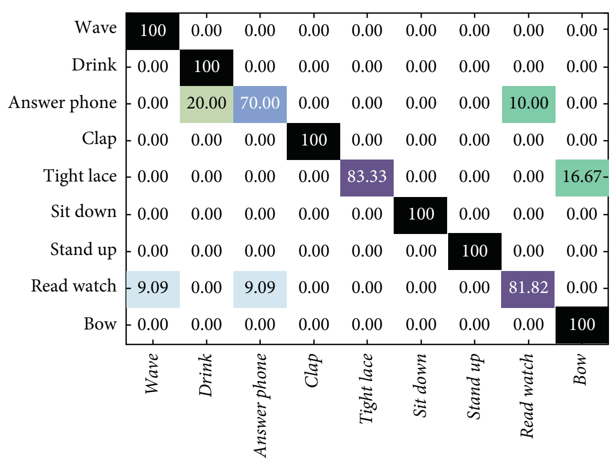


Figure 7: Confusion matrix of action recognition results using the Florence3D action database.

It can be concluded from Table 4 that although several CNN models with different convolution kernel size combinations can effectively classify the Lie group features of volleyball players extracted in this paper, there are differences in the classification effect. The main reason is that when different convolution kernel sizes process the features, the feature information obtained is different, compared with other weight combinations. When the convolution kernel size of the first convolutional layer is 13×13 and the convolution kernel size of the second convolutional layer is 8×8, relatively good recognition results can be achieved. Therefore, this paper selects the weight parameters to build the network model. In order to clarify the action recognition situation of this method in the Florence3D action database, this paper presents the correct recognition rate and error recognition rate of each action in the form of a confusion matrix, as shown in Figure 7. According to the results presented by the confusion matrix, among the 9 volleyball players' movements, 6 movements can be completely and accurately identified. For the other three movements, 2 of them have more than 80% accuracy. When two actions are similar, it is easy to misjudge while recognizing. For example, the action "answer phone" has a 20% probability of being recognized as the action "drink" and a 10% probability of being recognized as the action "read watch." All these three actions support lifting hands and arms, with similar action tracks and high similarity between actions.

5. Conclusion

This paper examines the action recognition mechanism used by volleyball players using a convolutional neural network (CNN). It first briefly introduces deep learning and common deep learning models and then delves into the network structure, working principle, and benefits of the CNN before presenting a CNN model and parameter setting for volleyball players' action recognition. Experiments were carried out on the open database Florece3D action, and the results show that the proposed method based on the Lie group feature and deep learning can achieve good recognition effect and has a strong ability of database transplantation. At the same time, compared with the existing methods from the literature, it has better recognition effect and robustness, and the computational cost is greatly reduced.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

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Research Article

Applications of Machine Learning in Public Security Information and Resource Management

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The data mining and big data technologies could be of utmost importance to investigate outbound and case datasets in the police records. New findings and useful information may potentially be obtained through data preprocessing and multidimensional modeling. Public security data is a kind of "big data," having characteristics like large volume, rapid growth, various structures, large-scale storage, low density, and time sensitiveness. In this paper, a police data warehouse is constructed and a public security information analysis system is proposed. The proposed system comprises two modules: (i) case management and (ii) public security information mining. The former is responsible for the collection and processing of case information. The latter preprocesses the data of major cases that have occurred in the past ten years to create a data warehouse. Then, we use the model to create a data warehouse based on needs. By dividing the measurement values and dimensions, the analysis and prediction of criminals' characteristics and the case environment realize relationships between them. In the process of mining and processing crime data, data mining algorithms can quickly find out the relevant information in the data. Furthermore, the system can find out relevant trends and laws to detect criminal cases faster than other methods. This can reduce the emergence of new crimes and provide a basis for decision-making in the public security department that has practical significance.

1. Introduction

With the accelerated development of modern technologies like communication, computers, and big data (known as high-tech), now other data mining and security technologies are increasingly used in our daily life, thus driving us into an information society [1]. However, illegal crimes have also shown new characteristics. It can be said that modern illegal and criminal acts are already in a period of rapid development. It is not difficult to find that, with the improvement of professionalization and high technology, cybercrimes, high-tech crimes, and so on obviously have the characteristics of the times. New criminal methods and forms of crime are also constantly being updated. In this new situation, the state has put forward two clear goals, namely, (a) request police force from science and technology and (b) revitalize police through science and technological education [2]. At the end of the last century, under the modern economic and social conditions, to achieve dynamic management and combat crime, the Ministry of Public Security has not hesitated to put forward the slogan "Strong Science and Technology," cultivate rapid response capabilities, and formulate comprehensive start-up coordination. Under the new situation, our operational strategy requires that we make full use of technology, strengthen the police's fight against crime, and improve the solution efficiency of public security work [3].

In the past ten years, the development process of the informatization and construction of public security organs is obvious to all, and progress has been made by leaps and bounds. The establishment of a public security informatization network that is all-round and not leaking is "vertical and horizontal to the end" [4]. All police types and businesses have also fully implemented information management. Similarly, the accumulation of a large amount of business data and some comprehensive applications are also underway. The main advantage of information management lies in the use of advanced computer technology to effectively manage existing information through certain methods, which in turn improve law enforcement efficiency and prevent new illegal behaviors. Finally, it can be very powerful to combat and curb criminal acts. However, at present, the intelligent analysis function is still almost in a blank state, so the massive business data accumulated in the work is limited to simple primary applications such as query, update, and statistics [5]. Hence, how to use the data mining technology to discover and use the hidden regular information behind these data to serve various management works of the department and even provide scientifically valuable evidence for the leadership to make decisions can be seen from this. Moreover, providing the police with some useful technical support and reliable references is an important subject that we will explore to solve these problems.

In this paper, a public security information analysis system, based on the data mining technology, is proposed that consists of two modules: (i) case management module and (ii) public security information mining. The former module is responsible for the collection and processing of case information, and the latter module preprocesses the data of major cases that have occurred in the past ten years to create a data warehouse. By dividing the measurement values and dimensions, the analysis and prediction of the criminals' characteristics and the case environment realizes a detailed analysis of the existing relationship between the environment and the type of case. This paper studies how to use the data mining technology to analyse the information of criminals and find laws and trends of criminal behavior, which is very important for improving (i) the ability of antiterrorism decision-making, (ii) commanding, and (iii) levels of comprehensive application of online information and (iv) strengthening the construction of a modern public security prevention and control system. The principal contributions of our work are as follows:

(i) We take the outbound and case data in the police records

(ii) Through multidimensional data modeling and preprocessing (big data), we obtain some useful information from the data

(iii) A police data warehouse is constructed, and a public security information analysis system is proposed, based on the data mining technology

(iv) A clustering algorithm divides instances into natural groups and distinguishes the hidden classes in the data instead of using predicted instance classes

(v) We use the proposed model to create a data warehouse based on the users' needs

The rest of the paper is organized as follows: In Section 2, we briefly discuss the related literature review. In Section 3, we analyse the relevant technologies of public security information systems. In Section 4, we describe the public security police information platform system and result analysis. Finally, Section 5 illustrates the final thoughts and several directions for future research.

2. Related Work

The method of clustering in public security data has been widely used. For example, Sun and Scanlon [6] have realized the related modeling of the criminal behavior of sexual assault through the method of clustering and self-organizing mapping. Gupta et al. [7] have figured out a way to cluster the investigation reports of crimes to achieve the purpose of unearthing the criminals of the case. The system can even analyse the criminal life of criminals. It not only analyses the correlation between cases and criminals but also realizes the establishment of visual crime classifications through clustering methods, and it can also realize construction by analysing specific criminal gangs. The main basis for the filing of criminals is the duration, severity, frequency of crime, and the nature of the crime. A relatively new comparison method is used to compare the similarity of all criminals, then comprehensively consider the differences in the four aspects to generate a variable distance matrix that can describe the crime career, and finally realize the clustering analysis.

In the past period, because criminal network analysis is a very specific case, it has attracted a lot of attention. Subsequently, the conceptual space method was also proposed. The purpose of this method is to extract the relationship between crimes from the summary of the case and generate a similar network of suspects. Through the weight of cooccurrence, by realizing the calculation of the relative frequency of the suspect appearing in the same case at the same time, the measurement of the strength of the relationship between the two cases can be realized. Through the hierarchical clustering method, the criminal network is divided into many subnetworks, and the interaction mode between the subnetworks is determined by the method of block modeling. Through the related measurement of the centrality, closeness, and proximity of the network, the important members of the criminal group can be found out. "CrimeNetExplorer" is a visualization framework as well as an automated criminal network analysis process [8]. Among them are the main stages related to criminal network analysis, such as structured analysis, criminal network creation, network division, and network visualization.

2.1. Public Security Information System. The research on data mining technology in the field of public security started relatively late. But in recent years, with the advancement of the processing police information, the number of police officers has increased, and police work has begun to use data mining and other related technologies. Kaur et al. [9] suggested the method of establishing a public security data warehouse, discussed how to mine public security data, and realized the relevant analysis of data mining and the overall framework of the public security data warehouse. Hossain et al. [10] defined the relevant attributes of the case, applied the correlation matrix, and realized the discussion of the relevant methods through the discovery model of the relevant cases. Aiming at some relatively small-scale criminal organizations, Li and Cui [11] have developed a way to explore the relationship between criminal organizations based on social networks. The relationship mining of criminal organizations is mainly to analyse the relationship between the members of the criminal organization and determine the key personnel in the criminal organization.

2.2. Data Mining Technology. Through the related academic research on data mining, the police department's ability to enforce law and combat terrorism will be greatly improved. Based on the specific characteristics of crime and related security tools, data mining technologies mainly include the following: information sharing and collaboration, intelligent text mining, security association mining, classification and clustering, spatial and temporal crime pattern mining, and we analyzed criminal/terrorist networks in six areas [12]. Although the research on the use of data mining technology in police work has been for a long time, there are not many related documents, and there are not many related research results. There are even a lot of relevant data mainly for studying small areas, there is no cooperative relationship between various studies, and the application is mainly realized through some experiments [4].

3. Analysis of Relevant Technologies for the Public Security Information System

3.1. Overview of the Data Mining Technology. Data mining is also called analysing data, which uses semiautomatic or automated tools to mine data and knowledge. The process of data mining is also more complicated. From the database storing large amounts of data, multiple steps, such as practical, previously unknown, and usable knowledge, are mined. Each step constitutes a complete process. Finally, the knowledge is used to make reasonable judgments and scientific decision-making. The main process of data mining is shown in Figure 1.

The general process of data mining technology is described in Figure 1. In the whole data mining, the business object is the basis to be studied, and data mining is carried out around the business object. If researchers can focus on the research business object, dig out the results and verify the accuracy of the results and then data mining can be completed correctly [12]. The contents of each step in the data mining process are as follows.

3.1.1. Analysis of Business Objects. First, it is necessary to clearly know what the goal of data mining is, and then the premise is to clearly analyse the business problems. Although it is impossible to predict the results of data mining, the problems to be studied and analysed are obvious. Therefore, you must be familiar with the business objects, clarify the problems that need to be explored, and plan a general direction.

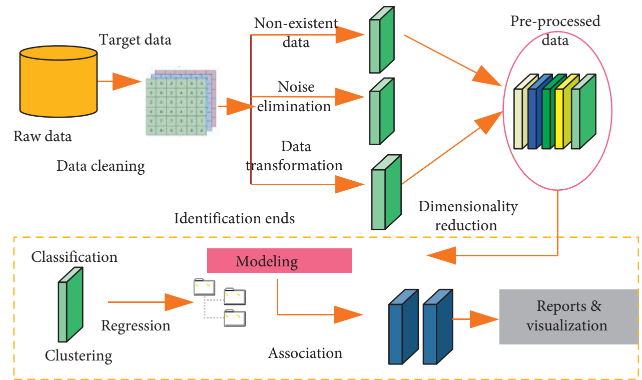

Figure 1: Process of data mining.

3.1.2. Data Preparation

(i) Data selection: collect all the information of related business objects, including internal information and external information, select data suitable for data mining from this information according to needs, and make a good choice on the data.

(ii) Data preprocessing: after screening the required data, estimate the quality of the data, compress the data set as much as possible, then sample the data, propose the types of mining operations that need to be applied, and make full preparations for the next analysis.

(iii) The purpose of data conversion is to unify the data types of the source data and the way in which the values exist. For example, convert continuous data into discrete classes and convert Boolean types into integer classes.

3.1.3. Data Mining. After getting the converted data, the next step is to mine. According to specific actual requirements, using appropriate algorithms to mine, it will automatically finish the rest of the work and finally wait for the result [13].

3.1.4. Analysis of Results. Analyse the results, evaluate, and draw conclusions. The analysis method generally selects visualization technology and outputs in the form of text or graphics. This is determined by the operation set by the user.

3.1.5. Application Integration. Based on the knowledge of the above steps, it can be found that if the integrated knowledge is integrated into the organizational structure and then put into the relevant business information system, then the business information system can realize application intelligence [14]. The above steps are completed in stages, each stage requires good professional staff in all aspects to achieve, and these personnel can be roughly divided into three categories:

(1) Proficient business personnel: such personnel are required not only to be quite proficient in business

and analysing business objects but also to put forward business requirements based on the characteristics of each business object and to mine them in a targeted manner so that business problems can be classified as data information.

(2) Data proficient personnel: this type of personnel can freely apply mathematical knowledge, can analyse business technical knowledge data by themselves, and can effectively extract value data information and transform business requirements into data mining for each step; you can also match the corresponding technology for the operation of each step [15].

(3) Proficient in data management personnel: this type of personnel is good at mastering data management technology; they can collect various data to form a data warehouse and can effectively use it.

Therefore, it can be known from the above that the process of data mining is a process of collaboration among professionals, and at the same time, it can be known that it is a highly integrated and high-investment technical process. Data mining needs to determine the requirements for data definition and selection of mining algorithms by determining each business object, analyse the technology and business of each stage of data mining, make timely adjustments, and finally make a scientific, clear, and reasonable mining result explanation. At present, the peak of informatization development is data mining, which also reflects the value of the highest application point of informatization.

3.2. Clustering Algorithm. In data mining technology, the clustering algorithm can be regarded as a very practical algorithm. From the current point of view, it is a well-deserved cluster analysis that is widely used in most applications, such as image processing, pattern recognition, data processing, and market research [16]. As a large piece of data mining technology clustering algorithm, it divides instances into natural groups and then distinguishes the hidden classes in the data, instead of using predicted instance classes. Cluster analysis can be used as an independent tool to obtain the approximate distribution of data and analyse each collection of data that combines similar properties. These collections can also be called clusters. Clustering analysis can map out some of the operating mechanisms of some instances in certain fields and create different connections and different relationships between the instances.

In the clustering algorithm, it is mainly necessary to determine the standard to measure the cluster centre and similarity. The clustering algorithm is different from the classification in data mining technology. The classification is the class stored in the known target database. What needs to be done is to extract and classify each record; the difference but similarity is that in the cluster. In the class algorithm, clustering is run without knowing the number of clusters in the target database. Its purpose is to classify all data. Under this classification, standards are specified based on attributes so that these data can be clustered. Minimize between and maximize between different clusters. In fact, the similarity of most class algorithms in clustering algorithms is related to distance. The reason is that there are quite a lot of data types in the database, so how to measure the distance between two nonnumeric fields? The discussion on this issue is also very intense, and many researchers have proposed similar algorithms. Each cluster obtained by cluster analysis can be treated uniformly in many applications. Clustering analysis algorithms can be classified into hierarchical method, split method, density-based method, and model-based method, and so on.

Generally, N-dimensional "space" is involved when using cluster analysis. This space can be used to solve the measurement problem. When performing data mining on clusters in N-dimensional space, the first thing to do is to survey the distance between the data and the data. Commonly used measurement methods include Minkowski distance, Manhattan distance, and Euclidean distance [17]. The measurement method of Minkowski distance is as follows:

$$\begin{aligned} s(a,b) &= \left\| X_a - \overline{X}_b \right\|^{1/r} \\ &= \left(\left(x_a^1 - \overline{x}_b^1 \right) + \left(x_a^2 - \overline{x}_b^2 \right) + \cdots + \left(x_a^n - \overline{x}_b^n \right) \right)^{1/r}, \end{aligned} \tag{1}$$

where $a = x_a^1, x_a^2, \ldots, x_a^n$ and $b = x_b^1, x_b^2, \ldots, x_b^n$ represent n-dimensional data objects; when the database represents the i^{th} record, there are n fields. Obviously, when using formula (1) to calculate the distance, to make the field meet the requirements, these fields must be processed. Of course, some applications do not make too many requirements for these fields. When r in formula (1) is 1, the distance is also called Manhattan distance. When the value of r is 2, the distance is called Euclidean distance. In the clustering algorithm, the weight of some data depends on the weight and lightness for a specific situation; for example, when it is necessary to implement cluster analysis of lost customers, the time since the last time the customer purchased the product should be given a very heavyweight. The weighted distance is shown in formula (2). Calculation method is as follows:

$$\begin{aligned} s(a,b) &= w \left\| X_a - \overline{X}_b \right\|^{1/r} \\ &= w_1 \left(\left(x_a^1 - \overline{x}_b^1 \right) + w_2 \left(x_a^2 - \overline{x}_b^2 \right) + \cdots + w_n \left(x_a^n - \overline{x}_b^n \right) \right)^{1/r}, \end{aligned} \tag{2}$$

where w represents $\| X_a - \overline{X}_b \|^{1/r}$, the weight of the total distance; when it is between 0 and n, the sum of all weights is 1. The clustering methods we generally use often include hierarchical clustering, grid clustering, partition clustering, density clustering, and simulated clustering.

3.3. Decision Tree Algorithm. Decision tree refers to the use of a tree structure to represent the decision set or the classification of data according to different data characteristics. The law is generated through data and the law is discovered. This is an effective method of supervising and inductive learning. In other words, the decision tree is a tree structure to represent the decision-making process, which can show the rules of what value should be obtained under certain similar conditions. Under normal circumstances, one event can cause two or more events and get different results. From this feature, the structure of the decision tree is from top to bottom, which is like a flowchart [18]. The top node of the tree is the beginning of the entire decision tree, also called the root node. Each branch of the tree represents a new decision output, and the child nodes on each node represent related attribute tests. We use decision-making related algorithms to pass and derive the number of child nodes.

The key to the problem is how to construct a decision tree model, that is, to build a decision tree. The process is roughly divided into two stages: the first is the tree-building stage, which is also called the recursive process, to obtain a tree; the second is the pruning stage, which aims to reduce the fluctuations caused by the noise in the training set.

3.3.1. Building a Tree. Usually, an important index to measure the quality of a node's split is based on the information gain. If a split has the highest information gain, then this is a split plan. Shannon proposed the theory of information and defined information (i.e., the amount of information) and Entropy as shown in

$$\mathrm{Inf}_i = \log\left(\frac{1}{p_i}\right), \quad (3)$$

$$\mathrm{Ent}_i = \sum_i p_i \log\left(\frac{1}{p_i}\right). \quad (4)$$

The term refers to a weighted average of the information volume of the system, that is, the average information volume of the system, and the information volume is the principle of the information gain index. Because the tree-building algorithm is a recursive process, only one of the splitting methods is needed to discuss and study the specific node N. Suppose that the training set pointing to N is S. This training set implicitly contains m different classes, distinguishing different classes C ($i = 1, 2, \ldots, m$). Let S_i be the number of like data in S; before splitting, the original is

$$E(c_i) = \sum_i p_i \log\left(\frac{1}{p_i}\right), \quad (5)$$

where p_i is any sample of the probability belonging to C_i. Since the information is encoded in binary, a logarithmic function with base 2 is set. According to the above formula, it is easy to get the total number, which is a weighted average.

3.3.2. Pruning. The most used method in pruning is the statistical method, which cuts off some branches that are not edged or even noise. There are many methods of pruning, usually the following two methods:

(i) *Synchronous Pruning.* When building a tree, if certain requirements are met, such as information gain or effective statistics reaching a preset threshold, the node stops splitting, and the internal node is regarded as a node on a leaf. Take the class with the highest frequency in the subset as the sign of the leaf node's self, and then store these instance probabilities to distribute the function.

(ii) *Hysteresis Pruning.* When building a tree, when the independent data in the training set is included in the decision tree and reaches the node if the class label of the training data is different from the class label of the leaf node, then it is called classification error. After the establishment of the tree is completed, the algorithm calculates the probability of each possible error branch passing through each internal node by weighted average and calculates the error rate instead of cutting the node. Because clipping can reduce their error rate, it is necessary to cut all branches under this node. This node is called a leaf. The error rate can be used to verify the test data independently included in the training set data, and the result is a decision tree with a minimized error rate.

4. Results Analysis

Under the protection of the security guarantee system, the public security police information platform comprehensively uses mainstream IT technologies such as server virtualization technology and middleware technology and builds a portal site, web application service layer, and database service layer based on the service architecture (design model), data storage, and backup layer and other four-layer structures. In Figure 2, the portal website is the unified entrance to the public security police information network and is an application system leading to public security information resources. The police have passed unified identity authentication and access control access to information resources with the single sign-on management system (PKI/PM) [18]; the web application service layer provides the web services and application servers required by the police information system. The web server will be based on the specific business needs of the police system. The functional components of the business logic layer are packaged into web services, and the web services provide business logic functions to the presentation layer for users to access; the database service layer provides the operating environment for the database system, and a well-designed database can ensure the stability and reliability of the system. The operation of the data storage and backup layer provides a unified storage, backup, and recovery management functions for the public security information resource database. The data lost in the system can be restored in the shortest time. It is composed of storage area network, cluster technology, dual-system hot backup, storage management software, and other components.

The security assurance system includes equipment security, supporting software security, network system security, application system security, data transmission and reception security, and computer room environment security. The construction of a security protection system must

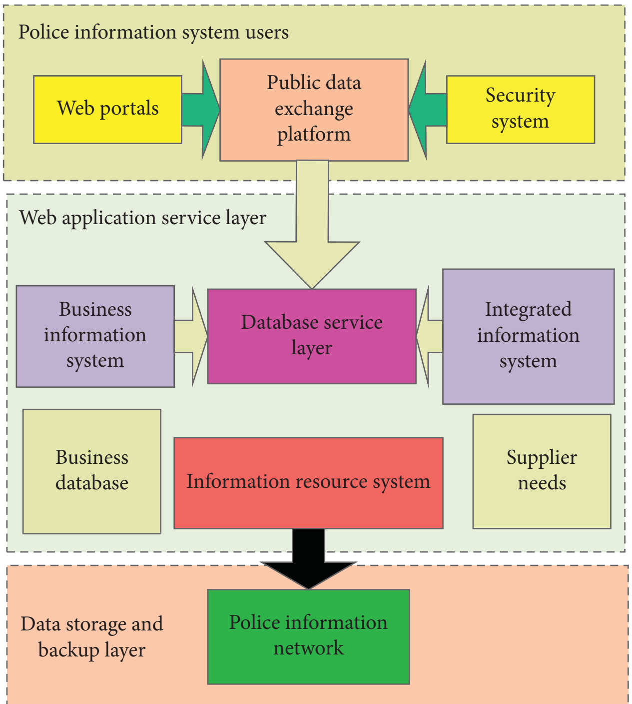

Figure 2: Public security police information platform system structure.

proceed from all aspects, closely combining organization, strategy, operation, and technology to form an all-round and integrated security protection system, so that the security of the police information platform can be truly guaranteed.

This system uses data mining technology to establish a data mart. The data comes from the information system of various functional departments of the public security organs and the criminal public security information analysis system. Based on the characteristics of the public security business, we use the very powerful SQL Server 2012 to implement the data processing process [19]. The SQL Server 2012 structure level type and new aspects, functions, and improvements can achieve multiple levels even in the same dimension. The establishment demonstrates multiple face-to-face dimensions, improves the ability to analyse multidimensional data sets, and improves the effect of multidimensional analysis. Microsoft SQL Server 2012 is an engine that provides a relational database, which can realize the storage of related case information and the establishment of a data warehouse. Microsoft SQL Server 2012 Integration Services development kit can load data, convert data, extract data, and other functions. Microsoft SQL Server also has the function of analysing data. It puts the data in the data warehouse through a series of processing and then puts it into a multidimensional cube so that analysts can easily analyse and query the data. The software system is implemented using Lava programming language, MyEclipse is used for development tools, and SQL Server 2012 is used for storage database.

4.1. Data Preprocessing. The role of ETL (Extraction-Transformation-Loading), that is, extraction, transformation, and loading, is to select and extract data from messy, inconsistent, and distributed data sources (including plane data, relational data, and logical data) to temporary layer, adjust dirty data, clean lengthy, convert format, integrate data, and finally load and unload the processed results in the target data warehouse. ETL processed result set provides a basic guarantee for online processing and data mining, whether ETL Success is related to the success or failure of the entire project, and it is also the most critical part of the project. According to the current experience of building data warehouses, when mining data warehouses, the entire process of ETL generally takes up most of the time, and when the amount of data is large, it may take longer. Therefore, we should pay more attention to it.

The entire process of ETL takes a long time and is very complicated, so the process needs to be managed. Management includes a series of operations such as ETL scheduling, error handling, management, and logging. At present, most ETL tools manage the process. To ensure high-efficiency operation, ETL generally runs in an automated manner in the background, so reasonable planning must be made. If the process fails, then we must intervene artificially. Therefore, both management and scheduling are particularly important in the entire ETL process. The Microsoft SQL Server 2012 Integration Services (SSIS) used in this paper is a relatively common modern ETL software that can produce a platform such as the main solution for high-performance data warehouses (including data warehouse conversion, extraction, and loading (ETL)) [20].

4.2. Detection of Crime Distribution in Public Security Information City. The type and quantity of urban crimes reflect the state of urban social security to some extent. When the social security situation occurs or is about to change, the distribution type and value of urban crime will also change accordingly. To conduct a comprehensive analysis of the urban social security situation and judge the current social security situation and changes, it is first necessary to preprocess the original data, extract valuable information from it, and classify redundant data and meaningless statistics. Eliminate and obtain the category that accords with the objective law, then find the characteristic that can describe the city's comprehensive public security situation in the complicated urban crime statistics, and analyse and extract the inherent characteristics implied by the crime data. This is the basis and premise of the relevant research in this thesis, and its quality is directly related to the effect and accuracy of the judgment of the social security situation.

This paper designs the following experiments to analyse the urban crime case data: (1) analyse and calculate the distribution characteristics of the annual case data of a certain type of case; (2) calculate the statistical distribution characteristics of the monthly case data; (3) calculate the statistical distribution characteristics of monthly cumulative case data; (4) comparatively analyse the data characteristics.

Since the number of days in 12 months is different, this paper takes 30 days as a standard month. Part of the original data is shown in Figure 3. In the experiment, the distribution characteristics of theft cases within 30 days were calculated

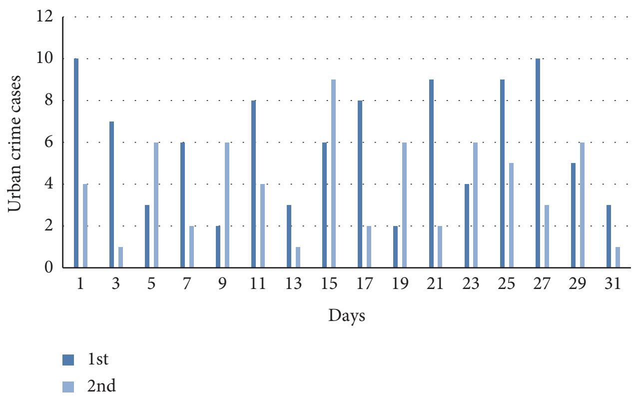

Figure 3: Number of crime cases in 1st and 2nd quarters.

Figure 4: Average distribution of theft cases per 30 days in a city in 2019.

by sliding with 15 days as a unit from 30 days. The experimental results are shown in Figure 4. In the experiment, it was calculated every 30 days (the last month was set to 36 days). The distribution characteristics of the accumulated data of theft cases and the experimental results are shown in Figure 5.

Through data processing and calculation, the chart shown in Figure 6 can be obtained, which can be compared with the daily statistical value, the statistical analysis value in units of 30 days, and the incremental statistical analysis value every 30 days. Figure 6 shows the total number of thefts in a city, as of records from the year 2019, and the mean values that are mapped to a Poisson distribution. Our investigation and observations from the datasets are discussed in the following paragraphs.

From the data analysis in the figure, we obtained the following observations and findings:

(i) Overall, the average Poisson distribution of crime incident data is relatively stable, fluctuating slightly around 5.12. In terms of the incident data of a certain type of case, the Poisson distribution better describes its mathematical characteristics, the distribution characteristics of different periods remain relatively stable and are affected by the crime incident data for a period, and the performance is a small fluctuation. Therefore, the Poisson distribution of urban crime statistics is used to describe its internal law, and the mean of the Poisson distribution over a certain period is used to quantitatively describe its characteristics.

(ii) The change in the mean value of the Poisson distribution describing the crime distribution is not sensitive to the statistics at a specific moment (e.g., there were 18 high-incidence cases at time 12, and the mean value of the Poisson distribution was basically unaffected), which shows that the characteristic data is not sensitive to occasional disturbances and changes accordingly only when the signal lasts for a period. Therefore, using the mean value as a feature can better prevent the occasional disturbance statistic from interfering with the feature, and the mean value can better reflect the overall trend of the statistic.

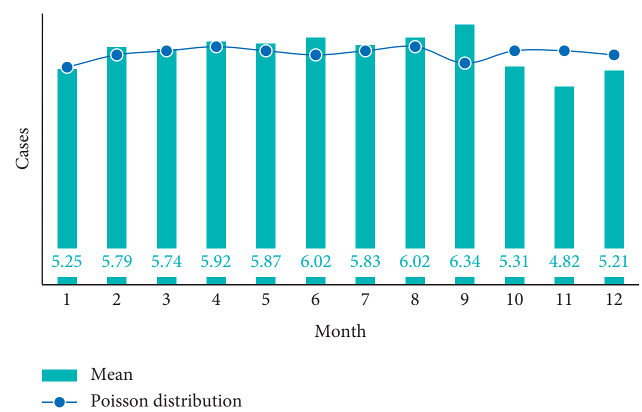

Figure 5: The average Poisson distribution of cumulative thefts per 30 days in a city in 2019.

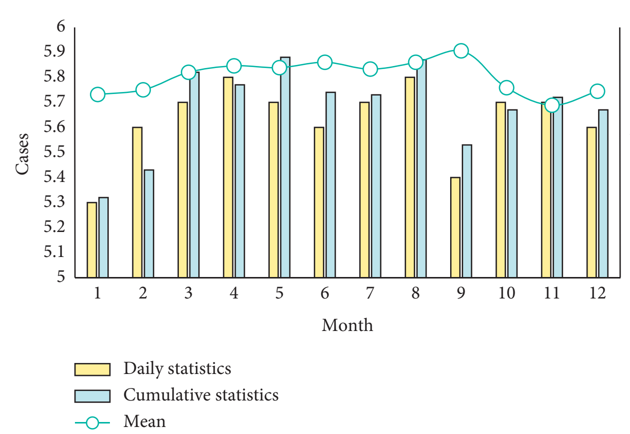

Figure 6: The number of thefts in a city in 2019 and the mean value of the Poisson distribution.

(iii) The variation range of the historical cumulative statistics of the Poisson distribution is much lower than that of the monthly statistics [21]. This shows that as the time range increases, the Poisson distribution tends to a certain steady state. However, within a certain period, its distribution

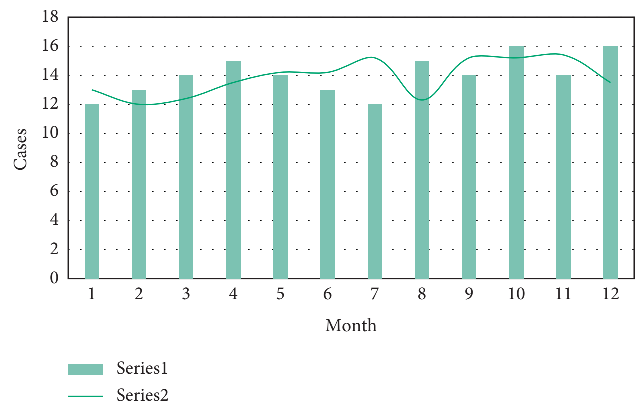

Figure 7: Estimated average value of theft cases in 2008 in 30 cycles.

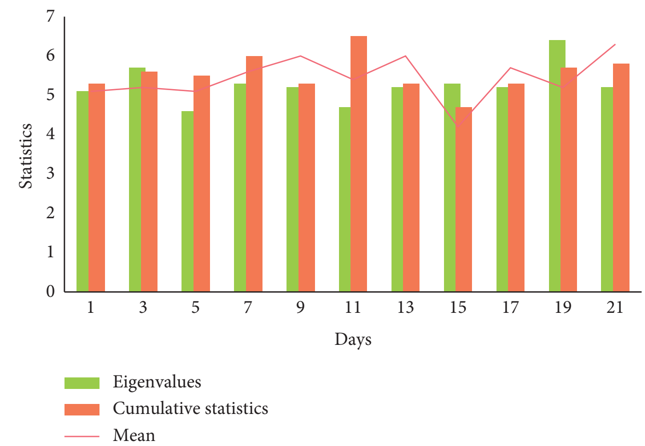

Figure 8: Three types of statistical mean comparison chart.

characteristics have changed significantly. This puts forward requirements for how to determine the period for calculating the eigenvalues of the Poisson distribution.

4.3. Experimental Detection of Feature Vector of Decision Tree Algorithm. The contradiction between the new requirements of public security information construction and the traditional business data separation model is increasingly prominent under the background of "intelligence information dominates police affairs." Building a comprehensive application platform for police information that collects various types of police, various businesses, and various types of data has become one of the new goals of public security information construction. In this general environment, various types of data are highly concentrated and highly integrated, which provides a good data foundation for public security information analysis and research and judgment. Compared with the previous comprehensive analysis and intelligence research and judgment, the allocation of research and design costs has changed a lot [22].

Unification, data transmission security, centralized collaboration of distributed data, and other important contents in the past information analysis and judgment almost no longer need to be considered under the new application platform, and most of its main energy and resources can be transferred to the analysis and processing of information; it provides great convenience for large-scale data processing and large-scale information analysis. According to the foregoing, the following experiments are carried out on the statistics of the high incidence of urban crime cases: (1) Starting from January 1, 2019, at intervals of 5 days, the mean of the Poisson distribution fitting is performed on the 30-day case data. (2) Starting from January 1, 2019, with 30 days as the base, 10 days of data are added for each statistics, and then the mean value of Poisson distribution fitting is performed.

The experimental results are shown in Figure 7, combining the experimental results of the previous experiment (for theft case statistics), it can be found that the average data of the crime statistics distribution basically stabilized after about 30 days after the start of the statistics, and after 60 days, the average was approximately a straight line. At this point, it can be considered that the impact of historical data on current data is small enough.

A comparison chart of statistical feature quantities of theft cases designed according to the above algorithm is shown in Figure 8. Among them, series 1 is historical cumulative data, series 2 is 30-day periodic data, and series 3 is data considering exponentially weighted decay. Obviously, most of the status of series 3 data is between series 1 and series 2; that is, series 3 is affected by current statistical values and historical statistical values when changing. Furthermore, we observed that series 3 better reflects the influence of historical data and current data on characteristic data.

5. Conclusions and Future Research Directions

The public security information analysis and mining system is an auxiliary analysis system, which can meet the relevant needs of public security and police affairs, and is a related expansion based on the data mining of case information. This paper starts from the application of data mining technology in police work, combining public security business and rich experience in case handling, to research and design a more common data mining system. The successful establishment of this system means that the investigative thinking of case-handling personnel is broader, and the case can be handled with higher efficiency than the manual system. The practice has proved that, through the technology of data mining, the relevant crime data in the public security information database can be processed and mined, and some related information contained in the data can be quickly found, trends and laws can be found, and cases can be solved as soon as possible. It can effectively reduce the probability of new crimes. It can provide relevant decision-making and basis for police work, which has very important practical significance [11, 23]. The research in this paper is the application of data mining technology in public security and the establishment of a case analysis mining system. The practice has proved that this design and implementation method is very effective and can meet the requirements of the police in handling cases.

This type of decision is made by an experiment, but an important question is whether, overall, there is a need to design and craft secure machine learning algorithms that way which can balance three aspects that are performance overhead, security optimization, and performance generalization. Other clustering techniques along with decision support systems should be used to further investigate the validity of our findings [22, 24]. Despite the use of machine learning, simple methods like regression analysis and their impact on the proposed system will be of great importance. Deep learning methods including LSTM, CNN, and GCN would also be considered as potential future work [11]. Finally, other related datasets should be used to generalize the findings of our research.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Research Article

Application of Transfer Learning Algorithm and Real Time Speech Detection in Music Education Platform

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Artificial intelligence (AI), particularly machine learning (ML) and neural networks (NN), has various applications and has sparked a lot of interest in the recent years due to its superior performance in a variety of tasks. Automatic speech recognition (ASR) is a technique that is becoming more important with the passage of time and is being used in our daily lives. Speech recognition is an important application of ML and NN, which is the auditory system of machines that realize the communication between humans and machines. In general, speech recognition methods are divided into three types, i.e., based on the channel model and speech knowledge method, template matching scheme, and the use of NN method. The main problem associated with the existing speech recognition methods is the low recognition accuracy and more computation time. In order to overcome the problem of low recognition accuracy of existing speech recognition techniques, a speech recognition technology based on the combination of deep convolution neural network (DCNN) algorithm and transfer learning techniques, i.e., VGG-16, is proposed in this study. Due to the limited application range of DCNN, when the input and output parameters are changed, it is necessary to reconstruct the model that leads to a long training time of the architecture. Therefore, the migration learning method is conducive to reducing the size of the dataset. Various experiments have been performed using different dataset constructs. The simulation results show that transfer learning is not only suitable for the comparison between the source dataset and the target dataset, but also suitable for two different datasets. The application of small datasets not only reduces the time and cost of dataset generation, but also reduces the training time and the requirement of computing power. From the experimental results, it is quite obvious that the proposed system performed better than the existing speech recognition methods, and its performance is superior in terms of recognition accuracy than the other approaches.

1. Introduction

Hearing loss affects an estimated 360–362 million individuals worldwide [1]. These figures are anticipated to grow by 40% on average by the year 2035. Hearing loss is normally due to two factors, i.e., age and noise. Hearing loss caused by both of these factors, i.e., aging or noise, is gradual and neither treatable, nor reversible. People with serious hearing problems are frequently socially isolated, which can lead to despair and a variety of other harmful outcomes. The most often used technologies for mitigating hearing loss are hearing aids and cochlear implants. Even advanced listening devices, on the other hand, create significant issues for the hearing impaired people, as they typically improve speech audibility but do not necessarily restore intelligibility in loud social circumstances [2]. Humans have been observed using the audio-visual aspect of speech to contextually reduce background noise and concentrate on the target speech in such situations. Furthermore, it is widely recognized that visual information aids in the resolution of acoustical ambiguities. For instance, people use AV cues in speech recognition, to properly interpret the conversation. The McGurk effect [3] shows that most people interpret a visual "ga" with a spoken "ba" as "da." The visual signals, particularly, give information on the location of articulation [4] and muscular movements, which can help distinguish between speeches with identical acoustic sounds.

Speech recognition is the auditory system of machines, which can realize the communication between humans and machines. In general, speech recognition methods are divided into three types, i.e., based on the channel model and speech knowledge method, template matching scheme, and the use of artificial neural network method [5, 6]. Compared with the traditional speech recognition methods, the artificial neural network (ANN) has a great improvement in modeling ability and speech recognition accuracy. The concept of deep learning (DL) is originated from the neural network system of the human beings [7]. In 2009, DL was first applied to speech recognition task [8]. According to the current development of speech recognition technology, speech recognition algorithms based on DL are mainly divided into long short-term memory (LSTM) network [9], deep neural network (DNN) [8], and convolutional neural network (CNN) [10]. CNN can obtain better robustness by using local filtering and maximum pooling technology. Therefore, CNN has received extensive attention in the field of image, video, and speech recognition in recent years [11, 12]. In recent studies, CNN has been applied in the field of speech recognition and has obtained promising results in terms of accuracy. Compared with previous work, the biggest difference is the use of deep convolution neural network (DCNN) [13, 14]. In speech recognition, there are differences in each person's pronunciation, which can be effectively removed by using DCNN and improves the accuracy of speech recognition systems [15, 16]. DCNN performs better on a large dataset, while, on small dataset, it fails to give better recognition results due to the problem of overfitting. DCNN needs a large dataset in order to prevent the problem of overfitting, so the training and selection of the DCNN architecture are very time-consuming, but an important step. At present, the method used to reduce the dataset size composed of images is the migration learning technique, in which the model architecture is trained on a large database and then tested on a smaller dataset, which is known as target database. The object recognition ability of transfer learning techniques can be found in different studies. Supported by transfer learning, several methods are used for visual identification and are widely used in image classification [17] and medical field [18, 19].

The goal of this study is to demonstrate the breadth of transfer learning's applications and performance on a heterogeneous and sparse database. The initial goal of the research work is to demonstrate that transfer learning is appropriate not just for situations, in which both the source and target database are the same, but also for situations when both databases are quite different. As a result, instead of pictures, a pretrained DCNN is used to learn verbal alphabets from A to Z. The AVICAR dataset has been utilized as a database, and it comprises verbal alphabets from fifty female and male speakers in various driving circumstances [20]. Each letter's audio recordings are converted into a spectrogram using the Fourier transform as part of the preprocessing procedure. The DCNN is trained using the produced pictures of the spectrograms, which are assembled by alphabets. As a result, there are 26 classes in the multiclass categorization problem. Furthermore, the dataset is kept short in order to test the efficiency of a pretrained network model using only the sparse database. The VGG-16 is selected as a pretrained DCNN [21]. It is a 16-layer Convolutional Neural Network developed by the University of Stanford's Visual Geometry Group and pretrained on data from ImageNet, a huge visual dataset for object identification. It is one of the most advanced DNN architectures that have been submitted to the ImageNet problem in recent years. In this article, you will find an overview of DNN models as well as a study of their computational needs, power consumption, and inference time [22].

This study uses DL and transfer learning techniques for speech recognition. The primary contributions of this study are given as follows:

(i) This paper proposes a method by combining DCNN algorithm with transfer learning to realize the speech recognition.

(ii) The use of DCNN algorithm improves the accuracy of speech recognition significantly, and the use of transfer learning technique, i.e., VGG-16, reduces the size of the dataset and helps in increasing the recognition accuracy.

(iii) The simulation results show that the transfer learning method not only reduces the time and cost of dataset generation, but also greatly saves and reduces the training time.

The remainder of this paper is organized as follows: Section 2shows the related work section, Section 3 illustrates the proposed methodology, Section 4 demonstrates the experimental setup and results analysis, while Section 5 concludes the research work.

2. Related Work

Automatic speech recognition (ASR) has evolved into a technology that is increasingly used in our daily lives. Word recognition performance has been proven to reach 100% in noise-free situations [23], but in noisy environments, performance decreases quickly. Model normalization, reliable feature extraction, and classification algorithm, as well as speech augmentation approaches, are some of the strategies that may be used to make ASR more resilient under these situations. Speech augmentation is a common method for this since it requires little to no prior information of the surroundings in order to successfully decrease noise in the voice signal and, as a result, increase identification accuracy. By focusing solely on the acoustic channel, each of these approaches aims to increase the quality of the ASR system. Using visual characteristics taken from the visual movements of a speaker's mouth region in combination with the auditory channel to increase noise resilience has been tried with moderate success. A substantial amount of research has been done in the subject of audio-visual ASR (AVASR) [24]. The comparison of these two dissimilar techniques (speech improvement vs. visual information fusion) to increase the noise resilience of speech recognition in unfavorable settings is of great interest. Due to the paucity of data that can allow such assessments, it has been difficult to determine whether acoustic speech augmentation or visual fusion is preferable, or whether both techniques can be coupled to further boost resilience in noisy situations. So far, most AVASR research has focused on increasing the visual information quality [24], with the implicit assumption that the use of visual information in the ASR system will enhance its resilience in the presence of noise.

Transfer learning is a popular method for decreasing the size of an image database. In this context, the saved weights and an existing architecture from a comparable problem are used to help learning on a novel developing challenge. Transfer learning involves training the model architecture on a massive training database afore transferring it to a new and considerably limited target database. A research study on the use of transfer learning techniques in different fields was conducted in [25], which aims to show the importance of transfer learning in various applications. Using transfer learning techniques, there are several ways to accomplish the task of visual recognition.

The main objective of this research is to investigate the applications and performance of transfer learning on a diverse and sparse database. The primary objective of the research study is to investigate that transfer learning is suitable not only when both the training and testing dataset are the same, but also when the two datasets are quite dissimilar. This study proposes a speech recognition system based on the combination of DCNN and transfer learning techniques. It is among the most advanced DNN architectures that have been submitted to the ImageNet problem in recent years. In this article, you will find an overview of DNN models as well as a study of their computational needs, power consumption, and inference time.

3. Proposed Methodology

This section of the paper describes the proposed methodology for carrying out the research study. The proposed methodology consists of different steps starting from dataset collection, data preprocessing, and the use of transfer learning techniques along with the deep convolutional neural network.

3.1. Dataset Collection and Preprocessing. AVICAR dataset comes from audio-visual speech corpus assembled from a car using various sensor devices. The University of Illinois scholars acquired and recorded it in 2004. The data was collected using eight microphones installed on the solar shield and four camcorders placed on the dashboard. Separated letters, contact numbers, separated digits, and phrases were the four types of speech that were gathered. All of the classes are captured in English from both 50 female and male speakers each, under five distinct driving circumstances, each with closed and open windows and idling, at the speed of 35 and 55 mph. The data is open to the public and is available without any cost. The audio data of isolated letters is collected in this study in all five driving situations for additional analysis. For every alphabet from A to Z, 200 audio files are selected for training and 50 audio files are selected for testing, respectively. For each letter, audio recordings of both female and male voices were saved in separate places. A total of 13000 audio files are generated, in which 10400 are selected for training, while the rest of the 2600 are used to test the model.

A spectrogram is created for each audio file. The frequency band of a voice is shown by the spectrogram of an audio recording. This technique is used in music, acoustics, radio, and speech identification. The Fourier transform is utilized to produce spectrum from voice files in this study. Figure 1 illustrates the spectrograms of the alphabets from A to D.

As the dataset is sparse, so the data augmentation is applied. Using label-preserving transformations, data augmentation approaches achieve the goal of artificially enlarging the dataset. Because of the existence of sparse datasets, data expansion is carried out, and label preserving transformation is used to realize the manual expansion of datasets. In order to enlarge the data, there is no need to generate new images, and the existing dataset is slightly modified, using different augmentation techniques like flipping, rotation, and translation. When these images are given to the neural networks, they consider it as distinct images. In this paper, different enhancement adjustments are tested, and the best results are obtained through random rotation and random width movement. The converted image is generated from the original image, which is produced on the CPU during the training of the last batch that is not required to be stored.

3.2. Transfer Learning Techniques. Training a DCNN on a short dataset, even when augmented with data, as demonstrated in many research papers [10, 11], does not yield sufficient results, ss discussed earlier that training the DCNN on small datasets gives unsatisfactory results. The results produced by this approach are different from the theory, so transfer learning techniques are used to solve this problem. In addition to the pretrained weights, there are different architectures that can be freely used for identification, fine-tuning, and feature-extraction. In this paper, the VGG-16 model is used for further work, because compared with other available models, the testing accuracy results of the VGG-16 model are much better than those of the other models. Figure 2 shows the VGG-16 architecture, which starts with an input image of size $244 \times 244 \times 3$ and then adds convolutional layer having 3×3 field size, a stride size of 1, as well as 5 Max-pooling layers having 2×2 window size. Next, 3 fully connected layers are used, and finally softmax is used as the activation function at last. For all the hidden layers, the rectified linear activation unit (ReLU) and activation function are used. This architecture is trained on ImageNet dataset. The ImageNet is an image data set, composed of the above 14M images. These images are manually categorized to identify the objects in the image dataset. A subset of over 1 million pictures is utilized to train the VGG-16 model, and the images are categorized into 1000 item categories to generate a wide range of image feature representations. Pretraining has the benefit of recognizing the correlations between objects and creating a structure, and forming classifications on a large and varying dataset that may be

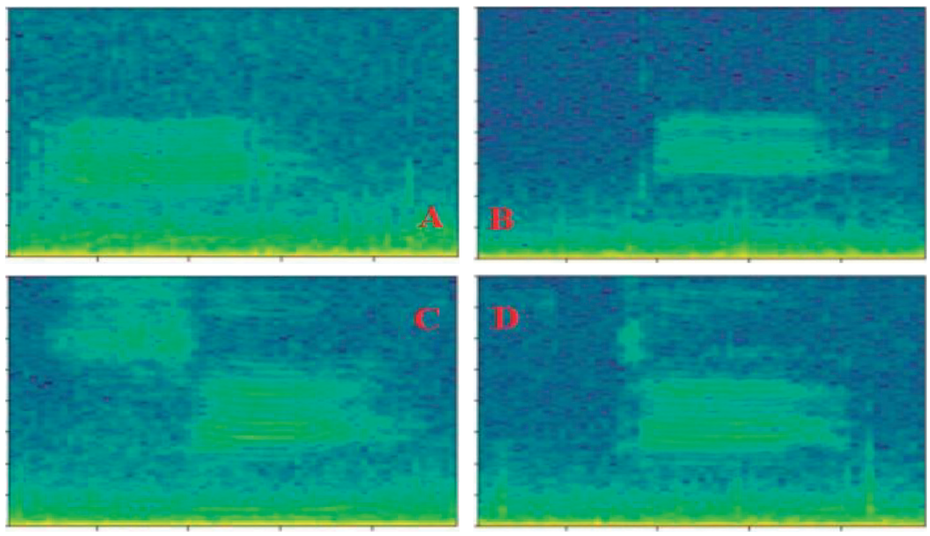

Figure 1: Spectrogram transformation of the alphabets from A to D using Fourier transformation.

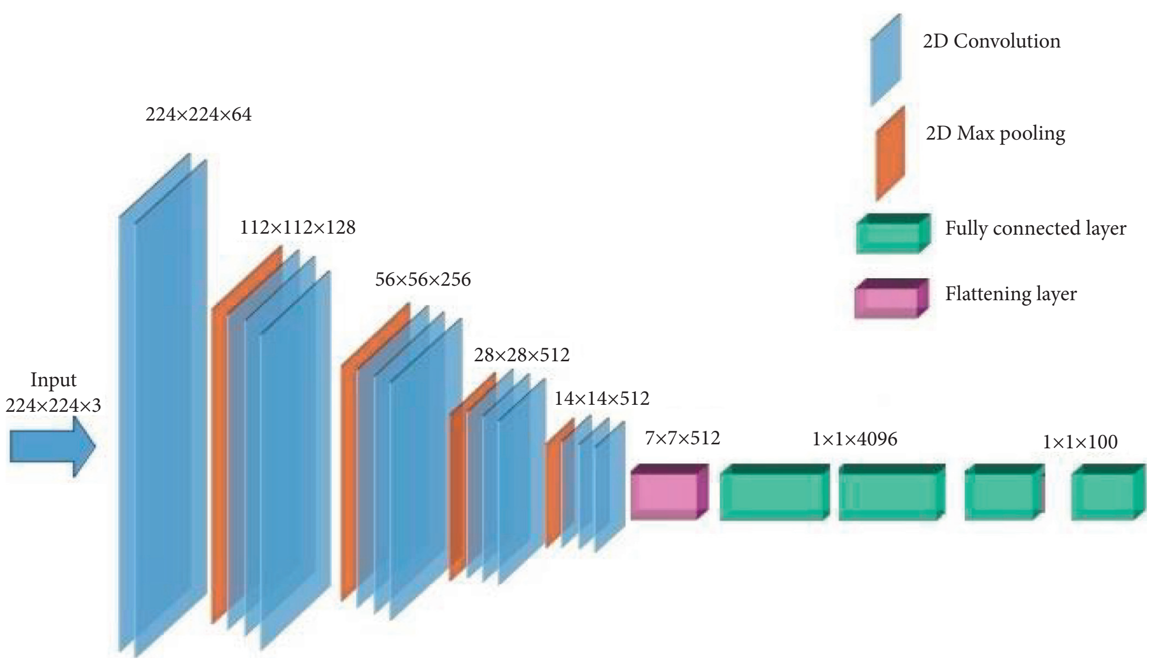

Figure 2: Schematic diagram of the VGG-16 transfer learning technique.

adjusted and gathered into new tasks to complete the redesigned tasks. Literally, it shifts learning progress to the current topic.

When utilizing limited datasets, the benefits of transfer learning for visual identification are widely documented. For small datasets and visual recognition, transfer learning is very suitable, especially in medical image analysis, in which usually a very small dataset is used, and DCNN is the preferred method of analysis of medical images. The pre-training of large data sets extracts useful features from the data, applies those features to the subsequently given tasks of small datasets, and proposes improvements in learning the sparse data.

4. Experimental Setup and Results Analysis

The experimental setup and simulation results are discussed in this section. The experimental setup includes a laptop system having the specifications of: core *i*7, 7^{th} generation, RAM of 16 GB, Hard disk of 500 GB, 128 GB of SSD, and 2.7 GHz processor operating on Windows 10. The IDE used for carrying out the simulations is Spider and *Python* is the language used for the implementation of the algorithms. For the implementation of AVICAR dataset Keras deep learning (DL) framework is used, which uses TensorFlow at the backend. In addition to various pretrained DCNN models, Keras is also used to implement the VGG-16 model as described earlier. The model comes with weights that have been pretrained and may be used for forecasting, extraction of features, and fine-tuning. In this method, fine-tuning is used to develop the proposed model. As shown in Figure 3, the pretrained VGG-16 model is altered by mangling the final fully connected layer prior to the last maximum pooling layer, expanding the global spatial average pooling layer (GAP) and two fully connected layers. GAP decreases the number of model parameters, eases the spatial dimension, and ensures that the model will not overfit. After that, a fully connected layer with a size of 11512, a linear predictor (ReLu), and a subsequent fully connected softmax layer with 26 classes follow the GAP. This is the number of classes required for the experimentation.

The upper layers of the VGG-16 architecture are trained using spectrograms produced by the data augmentation techniques, which improves the performance by artificially expanding the size of the data. The stochastic gradient descent optimizer (SGD) having a modest learning rate of 0.0004 is selected as an optimizer. The model is trained with a batch size of 8 for 25, 50, 100, and 200 epochs using audio data of both female and male voices separately, and a combination of both female and male voices. The pretraining class hours should approach to or within the range of training capacity. Table 1 shows the training results of accuracy in percentage.

From Table 1, it is quite obvious that a data set is composed of 5200 male or female voice files, and the voice test results of each gender can be received in an effective way. Training cannot produce similar results for the mix of male and female voices using a dataset of 5200 files. However, a dataset that contains double files, i.e., 10400 files, not only achieves the results of individual training, but it is even better than the results of individual training. It can be observed that, for the total test cases, the results that cannot be completed after more than 25 class hours of training can be obtained through 50 or more class hours of training.

Fine-tuning can be done in the second phase. Only the upper layers are used for training, while the lower layers are kept constant. The outcomes of the proposed design are investigated by altering the percentage fraction of frozen layers from 10%–90% in this study. Further, the outcomes of the training of female and male voices are examined independently, as well as with a dataset that includes both female and male voices. There are 5200 files in total across all datasets. Since a larger learning rate might cause misrepresentation of the pretrained weights, which are supposed to reflect excellent outcomes for the new model, a SGD optimizer with a modest learning rate of 0.0002 is employed for fine-tuning.

Table 2 illustrates the speech recognition accuracy after applying the fine tuning of the frozen layer.

It can be seen from Table 2 that female and male voices are tested individually as well as in combination. The results of overall accuracy are comparable with those of pretraining for female and male voices trained individually and in combination, and the accuracy of the combined male and female voices is lower as compared to the separated one. It can be seen that, under all experimental conditions, the best results can be obtained when the percentage of frozen layer is 10%–50%. When 90% of the layers are frozen, there is no training result at all. When the pretraining dataset is unrelated to the real dataset, freezing most of the layers and just training the final remaining layers is pointless, because feature fitness is insufficient, which may be increased by reducing frozen layers until a specific point.

Because of the inadequate findings in Table 1, the hypothesis that a pretraining above 25 epochs would be insufficient could not be asserted. In the context of fine tuning,

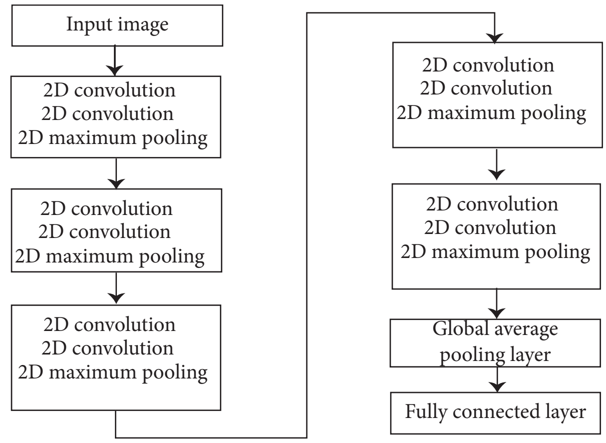

Figure 3: Improved VGG-16 model.

Table 1: Speech recognition accuracy under different training hours.

Research objects	Training hours			
	25	50	100	200
Female sex	29.30	36.19	40.60	41.30
Male	30.42	35.89	41.32	42.18
Female/male	22.24	29.32	29.80	30.87
Female/male (double)	37.82	43.21	45.26	46.32

Table 2: Speech recognition accuracy after applying the fine-tuning of frozen layer.

Research objects	Class hours	Percentage of frozen fine adjustment layer				
		10	30	50	70	90
Female/Male	25	64.29	61.29	61.52	54.30	23.60
	50	63.32	62.94	59.31	54.10	29.11
	100	63.89	63.62	61.36	53.29	34.30
	200	62.22	61.42	57.10	53.80	35.64
Female sex	25	76.25	77.20	74.61	65.14	35.58
	50	71.96	76.56	72.58	65.61	41.20
	100	76.62	76.36	74.25	65.72	39.76
	200	74.90	75.28	71.58	66.40	46.50
Male	25	73.10	78.66	76.79	71.24	25.10
	50	77.32	76.74	74.88	65.70	39.78
	100	77.80	76.87	74.71	66.68	43.86
	200	75.32	76.02	71.66	65.56	39.50

Table 3: Speech recognition accuracy after applying the fine-tuning of frozen layer.

Research objects	Class hours	Percentage of frozen fine adjustment layer				
		10	30	50	70	90
Male/Female (double)	25	78.76	80.42	78.21	71.89	41.40
	50	78.28	78.77	78.75	72.81	50.58
	100	79.69	80.40	79.37	70.88	48.60
	200	80.20	78.81	78.86	78.33	50.70
Female/Male	25	64.50	61.22	61.52	54.52	23.72
	50	63.31	62.90	59.31	53.19	29.19
	100	63.68	63.60	61.43	54.43	34.43
	200	62.21	61.50	57.23	53.80	35.56

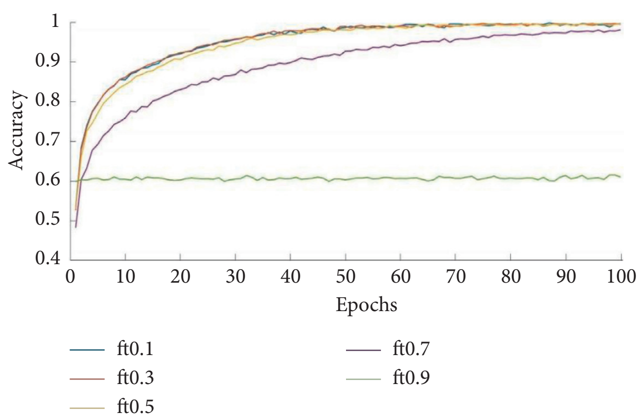

Figure 4: Training accuracy of 10400 male and female voice file sets with different number of frozen layers.

only 25 class hours of pretraining produces similar results as other test cases. Table 3 demonstrates that doubling the dataset improves training outcomes for both male and female voices, resulting in an accuracy of almost 80%, despite the dataset's limitation of just 10400 files.

It can be seen from the saturation of learning rate and accuracy in Figure 4 that more than 50 class hours of training is enough for fine-tuning, and the proportion of frozen layer is less than 50%, as assumed by the results in Table 2.

5. Conclusion

Automatic speech recognition (ASR) is a technique that is becoming more important with the passage of time and is being used in our daily lives. This paper mainly uses the combination of DCNN and transfer learning techniques, i.e., VGG-16, for speech recognition. The main goal of this study is to use transfer learning techniques for the speech recognition and to increase the recognition accuracy of audio speech files. Although utilizing a totally different dataset, the primary goal is to use transfer learning. Although different datasets are used, the simulation results show that the pretraining features are generally applicable even if there is a difference between the target database and the source dataset of the pretraining model. The other principal aim was to investigate transfer learning in the context of spoken letter identification on a limited dataset. In the application of speech letter recognition, transfer learning is used on small data sets. The simulation results show that, even for a very small dataset, it can detect voice letters significantly, but the recognition accuracy is slightly lower than that of the other methods using large datasets. However, only using the data set of 10400 male and female voice files, even if part of the audio data is recorded under noise conditions, the accuracy reaches nearly 80%. The application of small datasets reduces the time and cost of datasets generation and also reduces the time of training the model and the demand for computing power. The future work of this paper is to use more transfer learning techniques along with the ML and DL algorithms in order to improve the speech recognition accuracy using both the small and large datasets.

Data Availability

The data used to support the findings of this study are included within the article.

Disclosure

The paper extends the conference paper "Spoken Letter Recognition using Deep Convolutional Neural Networks on Sparse and Dissimilar Data" (https://ieeexplore.ieee.org/document/8702300) in 2019 IEEE International Symposium on Circuits and Systems (ISCAS).

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Research Article

An English Reading and Learning System Based on Web

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Learning management system (LMS) is a web-based system used to develop, implement, and assess a specific learning process. When designing an administration learning system, it is important to understand the general architecture and roles of each level of the system. In this study, we propose a web-based English reading learning system to address the drawbacks of existing methods in English learning resource management that include login impact, system response time, and user satisfaction. English reading materials are integrated using a feature model, and the adaptive recommendation system is built using the ID3 method. The design of the proposed English reading learning system was intended to employ a hybrid of software and hardware that will benefit a wide variety of groups, especially universities, colleges, and organizations. The statistic results showed that the proposed model is capable of meeting the functional objectives of English learning resource management, as well as having a rapid and accurate response time with high user satisfaction.

1. Introduction

Globalization has become an essential trend of social growth in today's economic society. Different nations' economic exchanges are also required for different countries to carry out social development, in which language, as the basis of communication, plays an important role. If someone knows only one language in their own country, they will be unable to stand out in the fast-growing international society, go overseas, and help the economy grow [1]. To reduce dependency on speculating, it is important to improve learners' capacity to grasp information from the ground up by expanding their understanding of English. English is the most widely spoken and understood language in the world. The value of English learning cannot be overstated. The primary problem in front of English learning is how to manage digital education and teaching materials, network courses, and virtual learning communities in order to adapt to changes in education and teaching settings brought about by the growth of modern educational technology [2]. English reading, as a vital connection to improving the English application level [3], must be prioritized. As a result, relevant academics have investigated certain English reading techniques, systems, and platforms with the hope of improving English reading ability using current means and technology [4].

Several researchers have proposed different teaching systems, that is, [5] suggests a revised design process for an English teaching system based on multimedia technology. The proposed system includes a stabler framework, use case diagram, and administrator interface to complete the hardware design. Lastly, the system software design is finished by enhancing the database using the error handling procedure and the background admin workflow. It was found that by using a multimedia-based English teaching system, the number of online courses could be increased, as well as the fluency of instructional videos. Similarly, a design technique for English video learning software based on smart mobile terminals is proposed in [6]. From the design goals, functional requirements, and software development environment, it briefly introduces the program. When it comes to software, it is important to understand how it works, and the precise functions of each module are described in depth. Testing shows that this approach has the benefit of a user-friendly interface, according to the results. Moreover, [7] develops a deep learning-based intelligent teaching system. The solution is divided into two components: online personalized learning recommendations and offline classroom quality two-way evaluation. Performance prediction and online learning behavior analysis based on deep learning are created in the online system, and learning emotion categorization is accomplished using image processing technology. It is possible to extract online learning behavior features, offline performance prediction, learning law analysis, and personalized learning recommendations using offline systems that use training target detection models, face detection models, and face segmentation models in combination with online systems. This data may also be used to evaluate and provide feedback on college teaching quality and student learning habits. According to the experimental results, the system has an easy and fast way to get information but also reduces a lot of time expenses, meets the new learning and teaching technique of integrating online and offline, and improves instructors' teaching efficiency and students' learning efficiency.

Although the approaches described above have yielded positive study findings and played an important role in enhancing English learning, there are certain issues in English learning resource management, that is, login effect, system response time, user satisfaction, on that need to be addressed further. Therefore, in this article, we propose a web-based English reading learning system. The major contributions of the paper are as follows to improve the English reading learning system:

(i) Finding word count and reading duration
(ii) Reading speed by highlighting and clicking on the desired text
(iii) Mod of complexity: if a certain book is very tough or a bit challenging, an adequate degree of difficulty level is a little easy or very easy
(iv) An appropriate vocabulary-leveled reading selection
(v) Students' practice time can be automatically recorded

The rest of the paper is organized as follows. In Section 2, a proposed system model design of the English reading and learning system. The establishment of system software design collaborative optimization model process analysis is conducted in Section 3. The experimental results and discussion are further summarized in Section 4. Finally, Section 5 concludes the paper with a summary and future research directions [8].

2. Design of English Reading and Learning System

2.1. System Overall Architecture Design. Internet applications in the web mode have decentralized, real-time, and non-real-time interactivity. Web can meet the individual needs of most users and provide users with more opportunities to participate in Internet content production. The process of users participating in the production of Internet content is a process of real-time interaction between users and web servers. At the same time, the information transmission between different users of the same website in the WEB environment reflects non-real-time interaction. The "one-to-many" and "many-to-many" dissemination modes of the web have broken the information monopoly of traditional portal websites and realized mutual discussion and communication among multiple users.

According to the web model, the general structure of the English reading learning system is built on. Building the English reading learning system is meant to enable decision-makers to create learning resource suggestion methods through effective data gathering [9] so that weak learning linkages may be targeted. Its general structure is depicted in Figure 1. A total of five layers make up the system's general architecture, including the basic layer, data layer, service layer, and application layer, as well as the user level. The basic layer is the bottom layer of the system architecture. It is mainly based on the web to support the network services of the English reading learning system to meet the system's network service requirements. The data layer is the second layer of the system framework. This layer mainly operates and manages system data, including resource data, management data, behavior data, and evaluation data. The resource data include English reading resources, cognitive style test resources, and English reading ability test scale resources. Management data includes student personal information and software information. Behavioral data include learners' behavioral data, self-designed learning plans, and semester tests. Evaluation data include answer exercise result data.

The data layer is mainly responsible for the collection, processing, exchange, and storage of the above data. The service layer is the middle layer of the overall system architecture, which is used to connect the data layer and the application layer. The service layer is mainly used to support the implementation of the system in the application layer to provide users with application services, mainly using the ASP.NET WebAPI framework, which can quickly provide APIs for HTTP clients to create web services [10]. The application layer presents the adaptive learning services that the English reading learning system ultimately provides for learners, which mainly embodies the functions of login and registration, learning resource recommendation, independent exercises, context acquisition, and learning records provided by the system. Among them, log-in and registration are used for identity verification, reading ability, and cognitive style testing; learning resource recommendation is mainly used to recommend learning resources for learners.

Autonomous practice is mainly used for learners to independently select learning modules and set learning plans according to their own learning needs. Context acquisition is mainly to obtain the environmental volume of the current user's geographical location, to judge the impact of the noise of the geographical location volume on learning. Learning records mainly record the basic information and learning behavior of current learners. The user layer is mainly the layer where the system directly contacts users and is the outermost layer of the system architecture, providing learning services for users of the English reading learning system.

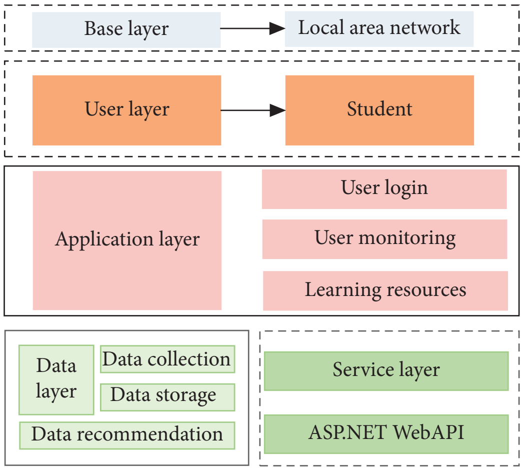

Figure 1: Schematic diagram of the overall system architecture.

2.2. Subfunction Modules. Based on the overall structure of the English reading learning system and the functions of each level, a specific analysis of the subfunction modules of the system hardware is carried out.

2.2.1. Reading Teaching Module. Teachers may use the reading teaching module to release course content, update the test question bank, and set up English reading assignments. Students can use the module to participate in reading exercises, complete unit exams, and take the final test at the end of the course. There are three primary components to the reading teaching module: reading learning, teaching business, and reading exams (or quizzes). In particular, the reading submodule is separated into two categories: time-limited reading exercises and unrestricted reading activities using a database; academic outcomes from both modes will be stored in a single location. The academic results of the two modes will be recorded in the database. The reading test submodule can be further divided into unit tests and final tests. Both tests can include objective questions and subjective questions.

2.2.2. Content Management Module. The content management module is mainly responsible for the organization, publication, modification, and deletion of articles in the system. It uses visual editing technology to provide users with a friendly operation interface and allows users to publish content in various formats such as slides, Flash animation, video, and audio [11]. Users can evaluate the usefulness of articles, and each evaluation will bring users reward points. Users of different levels will be given different permissions. Ordinary users can view and rate the content of articles, users with higher levels can publish, modify, and delete their own articles, and administrator users can manage all articles. After users share content, there will be corresponding points rewards.

2.2.3. System Administrator Module. There are a lot of things that the system administrator module is in charge of, such as setting up and maintaining basic parameters of system functioning. Semester setting and course setting comprise course administration. The semester setting determines the time interval for students to learn online, and students can only conduct online learning assignments within the defined period. In User Management, the administrator may edit all user information, such as passwords and e-mail addresses using an interface. Users and classes can be imported in batches when semester settings have been completed. These contain student ID (the unique identifier in the system), name, and gender and class/teacher information. Additionally, it allows users to upload documents in Excel format as well as replace existing entries.

2.2.4. User Management Module. After starting the system, the user directly enters the login interface. If the user does not register, user needs to register first. After successful registration, user returns to the login interface to login to the system. The specific login registration process is shown in Figure 2.

On the homepage of the software, the user chooses to enter the user management system, and then the system will automatically jump to the login module of the software. After the user enters the account and password in the login module, click “login.” At this time, the entire system will perform background data in contrast. If there is no user information, it will prompt that the user does not exist. If it exists and the username and password are consistent with the background, then login to the homepage. The registration interface contains multiple edit text boxes, such as username, mobile phone, and confirm password. There are two buttons at the bottom: one is the registration button and the other is the reset button. If the user is not registered, click “register now” to jump to the registration interface. At this time, the set on click listener is mainly triggered, and then the register function is called to execute. Click “reset” to clear everything in the text box so that users can fill in personal information. It mainly uses the submit button to submit the newly filled data to the backend server by calling the commit function. The customer service system is very important whether it is in the current system or any user system. Whether the customer service system in a system is perfect is directly related to whether the design of the system is friendly or not, and whether the system design is carried out from the user’s point of view. This article designs the online customer service query process, and the result is shown in Figure 3.

From Figure 3, the online customer service query module design process first, if a user has questions, he or she should go to the online customer support system and contact customer care. It will then be determined whether there is online customer service. As soon as free customer service becomes available, the user will wait in line and be shown how many others are waiting. The user will be assigned the idle customer service until there is one available in the system. After the consultation, the online customer service process is completed.

3. System Software Design

Based on the hardware design results of the English reading learning system, in order to further improve the application

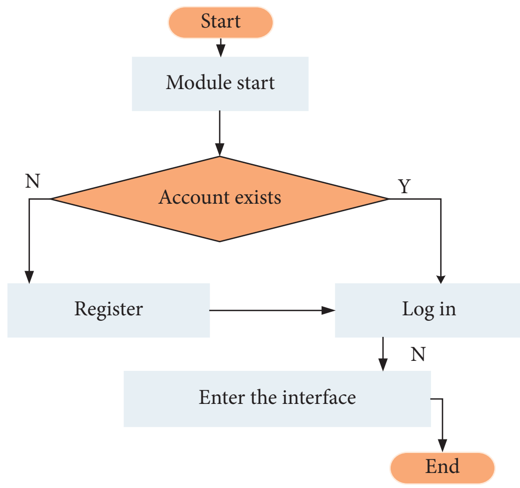

Figure 2: User login flowchart.

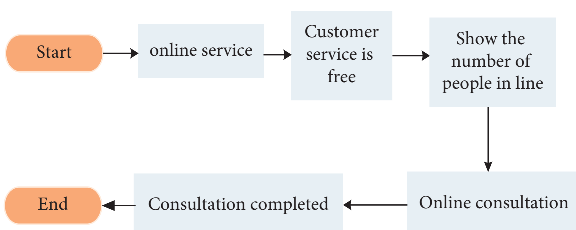

Figure 3: Schematic diagram of the workflow of the customer service query module.

performance of the system, the software algorithm is designed.

3.1. The Integration Method of English Reading Resources Based on the Feature Model. The creation of a feature model is required for the system to be able to represent the learners' learning characteristics in a timely, effective, and accurate manner. Given learners' online learning experience and system efficiency, characteristic model parameters are updated online in a timely way for learners to add friends, add collections, and do other activities that are less expensive for the system as a whole. If you are adding courseware labels, or performing other actions that require a substantial amount of processing, you should use the offline update technique. It is important to update the learner's feature model while doing so. In this case, raise the weight of the new interest subject if it is possible to retrieve it and delete the feature subject if the retrieval result is null.

The model is adjusted according to the most recently updated time t and the current time t_1. The current topic interest degree is accumulated as the latest interest degree value, and the model time is adjusted to t_2. The model update calculation method is

$$y_{ij} = \operatorname{sgn}(y)_a \sqrt{|y|^a - \left(\frac{\delta}{|t_1 - t_2|}\right)\vartheta^a}. \tag{1}$$

In the formula, y_{ij} represents the interest degree after the learning courseware is updated; $|y|^a$ represents the learner's interest in the learning courseware calculated by the current calculation; ϑ^a represents the interest degree of the learning courseware recorded last time; a represents the adjustment factor. The larger the value, the learner characteristic model also changes over time. The decay speed is slow and vice versa, which indicates that the decay speed is fast with time.

The feature model contains the learner's attribute information gender, age, and so on, vectorizes the information, assigns weights, and uses the cosine similarity method to calculate the background similarity between learners:

$$S(p_1, p_2) = \frac{1}{n-m}\sum_{i=1}^{m} z_i - \sqrt{\left(x - \eta^i\right)^T\left(x - \eta^j\right)}, \tag{2}$$

where $S(p_1, p_2)$ represents the similarity between learners p_1 and p_2, η^i represents the learner's ith vectorized information, and η^j represents the weight of the jth information.

In the calculation of domain ontology similarity [12], the specific topic that the user is interested in has a corresponding weight value, and the similarity is calculated by combining the domain ontology and its learner's scoring information on the learning courseware. The user-interested topic dataset is $E = \{e_1, e_2, \ldots, e_N\}$, $\varphi(e_c, e_v)$ is the two topics of interest e_c and e_v, which are the closest to the same category node in the ontology, and the semantic similarity calculation formula of the topics of interest e_c and e_v in the ontology is as follows:

$$S(e_c, e_v) = \frac{\varpi(e_c, e_v)}{\mu(e_c) + \mu(e_v)} \times d_k, \tag{3}$$

where $\varpi(e_c, e_v)$ represents the semantic similarity of interest topics e_c and e_v, $\mu(e_c)$ and $\mu(e_v)$ both represent the depth of the path from the root node of the same resource in the ontology to the user label, and d_k represents the path length from the root node of the same resource in the ontology to the nearest common ancestor nodes of e_c and e_v. The data range of $S(e_c, e_v)$ is $[0, 1]$, when $e_c = e_v$; that is, the two topics are the same, $S(e_c, e_v) = 1$; the similarity value of the interest topic increases as the depth of the common ancestor node increases.

In the integration of English reading resources [13], the integrated data resources include learner scoring dataset, predicted scoring value, and data recommendation. Set the learning courseware dataset as $Y = \{y_1, y_2, \ldots, y_n\}$, the learner dataset as $X = \{x_1, x_2, \ldots, x_n\}$, and the learner's scoring of the courseware denoted as $\{(y_1, h_1), (y_2, h_2), \ldots, (y_n, h_n)\}$; the grading set of y_k is $\{(z_1, h_1), (z_2, h_2), \ldots, (x_n, h_n)\}$, and the set of courseware that X_k is interested in is $X_q = \{y_n, \ldots, y_m\}$. To predict the scoring data of X_k courseware on $A = \{x_i, \ldots, x_j\}$, the specific equation is

$$T_{ij} = \left\{\frac{\left[\sum_{i,j=1}^{n}\left(x_i - x_j\right)^2\right]}{\left[\sum_{n=1}^{N}\left(x_n \times \sigma_k\right)^2\right]}\right\}^2. \tag{4}$$

In (4), T_{ij} represents the scoring result; σ_k represents the similarity of the scores of learners. It was determined that the similarity of interest themes as well as semantics and scores could be merged into the integration of English reading materials, using the analysis, and calculations described above.

3.2. Adaptive Recommendation Algorithm for English Reading Resources Based on ID3 Algorithm. Aiming at the fusion of learner characteristics and resource model characteristic data obtained in the context of English reading learning, an adaptive recommendation algorithm for English reading based on the ID3 algorithm is designed. From the basic idea of the algorithm, the initial recommendation of resources and the adaptive recommendation of resources based on the ID3 algorithm, the design of the adaptive recommendation algorithm for English reading is described [14].

The algorithm selects the attribute with the highest information gain as the test attribute of the current node, which minimizes the amount of information required for data classification in the result division and reflects the minimum randomness of the division. For the known classification attributes, the decision tree is constructed from top to bottom, divide, and conquer. Starting from the root node, the data sample set is calculated, and the data sample is divided into several subsample sets according to the calculation results, and each subsample set forms a new subnode. When the given conditions are not satisfied, the process of iterating to establish the decision tree continuously. In the generated decision tree, each non-leaf node corresponds to a non-category attribute, the branch represents the value of the attribute, and the path from the tree root to the leaf node corresponds to a rule, so as to obtain the expression rules and realize the recommendation of resources. ID3 algorithm is suitable for processing large-scale data, with strong learning ability, simple algorithm principle, easy understanding, fast classification speed, and easy to explain classification rules.

Taking V as the training set, the target attribute G of V has M possible class label values, $G = \{g_1, g_2, \ldots, g_m\}$; the probability of G_i appearing in all samples is I, $I = 1, 2, \ldots, M$; then the information entropy contained in the training set V is

$$\zeta(V) = \sum_{i=1}^{n} \varphi_i \log_2 \kappa_v, \tag{5}$$

where φ_i represents the probability that any sample belongs to G_i. Since the information is encoded in binary, the logarithm in the formula is based on 2. Assuming that attribute R has f different values, thus dividing into f sample subsets $V = \{v_1, v_2, \ldots, v_f\}$, the information entropy of the sample subsets after dividing V by attribute R is

$$\zeta_R(V) = \frac{\int_i^n f\left|V_f - v_f\right|}{\left|V_i\right|}, \tag{6}$$

where $|V_i|$ represents the number of samples contained in sample subset V_i and $|V_f - v_f|$ represents the number of valid samples contained in sample set V. Assuming that the sample dataset before the division is V_1, and the attribute B is used to divide the sample set V_1; the information gain $\partial(V_1)$ of dividing V_1 according to the attribute B is the entropy of the sample set V_1 minus the entropy of the sample subset after the attribute B is divided V_1:

$$\partial(V_1) = \Phi(V_1) - \Lambda(V_1). \tag{7}$$

Calculate the information gain of each attribute according to formulae (5)–(7). The greater the information gain, the purer the sample subset of attributes and the more conducive to classification. Select the attribute with the largest information gain as the test attribute of the sample set, construct a node, create a branch for each value of the attribute, and divide it continuously so as to build a decision tree and obtain rules, so as to recommend English reading and learning resources for learners in subsequent learning. In order to further improve the effect of resource recommendation, the multiobjective optimization problem of online learning resources is decomposed into many single objective subproblems by Chebyshev decomposition method, and a unique weight vector is given to correspond to it.

(1) Calculate the weight vector of online learning resources. To solve the online learning resource recommendation model based on multiobjective optimization strategy [15, 16], first decompose the online learning resource problem so that each online learning resource subproblem corresponds to a θ vector and calculate the weight vector of the online learning resource subproblem:

$$\theta_{ij}^2 = \frac{\hat{u} \cdot \left|\theta_{\max} - \theta_{\min}\right|}{\operatorname{rand}(N, 1)}. \tag{8}$$

In the formula, $\hat{u}$ represents the subproblem in the multiobjective optimization problem, $\theta_{\max}$ represents the number of online learning resources, and $\theta_{\min}$ represents the amount of resource redundancy [17].

(2) Vector sorting of online learning resources subproblems. Because the neighborhood strategy in the evolutionary algorithm is to use similar vectors to optimize the current vector, it is necessary to calculate the distance between each weight vector and sort according to the distance to find the neighborhood of the current particle. The distance between each weight vector can be calculated by the following:

$$D\left(p_i, p_j\right) = A_{ji}(L) - A_j(L). \tag{9}$$

(3) Determine the current learning resource neighborhood. According to (9), the particle neighborhood is obtained, that is, several learning resources that are similar to the current learning resources. Let O be the number of learning resources randomly selected among the number of learning resources, and $O = 2$.

Table 1: Verification of front-end login function.

Test	Specific description
Test type	Management interface
Test mode	Manual
Test target	Registered account users can login to the system
Prespecification	After registering an account on the website, the background system passes the review
Expected result	After login, the user can communicate in the download area and the discussion and exchange area; if the login fails, a prompt message will be displayed
Testing process	Enter the username and password in the login page and click login
Test results	Pass

(4) Solve the average fitness of the learning resource domain. If two learning resources $s_i(x)$ and $s_i(y)$ are randomly selected from the neighborhood, the average value of the neighborhood is

$$\overline{S_i} = \frac{1}{N}\sum_{i=1}^{n}\left(\overline{s_i(x)} - \overline{s_i(y)}\right)^2. \tag{10}$$

(5) Give particles the ability to explore new areas. In the later stage of optimization, the algorithm is easy to fall into local optimization, and it is difficult to find the global optimal solution. Therefore, the ability to explore new regions is added to the algorithm used in the online learning resource recommendation method, in order to increase the ability Ψ of the algorithm to explore other regions in the solution space, improve the convergence ability of the algorithm, and explore new regions:

$$\Psi = \frac{|R_s|}{\overline{S_i} \times p_s}. \tag{11}$$

4. System Test

As part of a simulation experiment, a test is conducted to determine whether or not the planned English reading and learning system based on the Web is successful and complete. Based on comparing and contrasting English video learning software based on intelligent mobile terminals and enhanced English teaching systems using multimedia technology, it is possible to determine the advantages of the developed system.

4.1. System Function Test. The experiment tests the foreground login and background resource management of the designed English reading learning system, which are described in Tables 1 and 2, respectively.

In Tables 1 and 2, we can see that the front-end login and backend resource management functions of the developed system passed the tests. This shows how effective and capable the system in this article is at managing the teaching of the English reading learning system is.

4.2. System Performance Test. System performance verification is carried out to further evaluate the application impact of the developed system in real applications. Different techniques are tested based on the system response time and user satisfaction. The results are shown in Figure 4. Figure 4 shows that as the number of online users continues to grow, the system response time has continued to increase. As a result, there has been an increasing trend in design methods for English teaching systems based on multimedia technology and English video learning software based on smart mobile devices. Through the comparison of specific data, when the number of online users is 300, the response time of the designed system is 0.3 s, the response time of the improved design method of English teaching system based on multimedia technology is 1.2 s, and the response time of the design method of English video learning software based on intelligent mobile terminal is 0.9 s. When the number of online users is 600, the response time of the designed system is 0.9 s, the response time of the improved design method of English teaching system based on multimedia technology is 1.7 s, and the response time of the design method of English video learning software based on intelligent mobile terminal is 1.5 s. The comparison shows that the response time of the designed system is shorter, indicating that it is running speed is faster and the system performance is better.

On the other hand, a comparison of user satisfaction with the system is made. The survey subjects are 200 students from different classes at a university. To teach online English reading to the case class, a variety of systems is employed. The questionnaire will be handed to the students at the end of the course. The questionnaire has a 40-minute response period to determine the students' level of satisfaction with the educational environment. Table 3 summarizes the results.

Table 3 shows that the student's satisfaction with the developed system is considerably greater than the enhanced design technique of the English teaching system based on multimedia technology and the design method of English video learning software based on an intelligent mobile terminal, as shown in Table 3. There is a substantial difference between this system's maximum score of 95 and the greatest score of older systems of 79. Thus, the proposed system is superior to the old system not only in terms of system function but also in terms of performance.

4.3. Evaluation of Collective Learning Behaviors. Reading behaviors were split into two categories as part of the proposed web-based English Reading Learning System: learning and learning-unrelated behaviors. Individual, intergroup, and intragroup reading were among the learning-

Table 2: Verification of background resource management functions.

Test	Specific description
Test type	Management interface
Test mode	Manual
Test target	The administrator implements editing processing on resources
Prespecification	Backstage administrator login
Expected result	The client analyzes whether the resource has been edited before or is empty and then submits the relevant resource to the database
Testing process	In the embedded development introduction management interface, click the category-based search option, select a resource point, and click the edit, delete, and add buttons
Test results	Pass

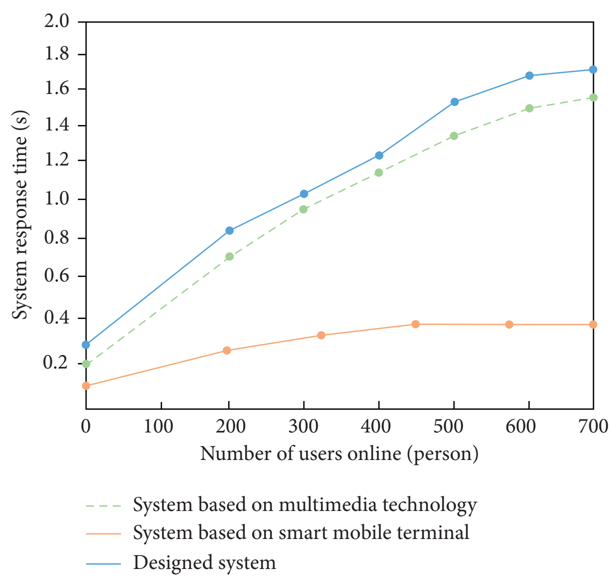

Figure 4: System response time comparison results.

Table 3: Comparison of user satisfaction.

No. of students	Designed system	Multimedia technology	Mobile technology
20	87	75	70
40	89	77	74
60	89	76	70
80	88	70	69
100	87	79	75
120	90	72	78
140	91	73	73
160	93	73	70
180	95	71	75
200	90	76	79

related behaviors. The frequency of each type of behavior in each group is depicted in Figure 5. According to chi-square analysis, the frequency of learning-related and learning-unrelated behaviors was significantly greater in the experimental group than in the control group (χ^2 (1, 1) = 91.32, p 0.05). As seen in Figure 5, students in the experimental group concentrated on reading activities. Figure 5 also shows that benefit from collaborative reading behavior both intra- and intergroup, particularly intergroup behavior due to the usage of peer-to-peer internet-based telephony.

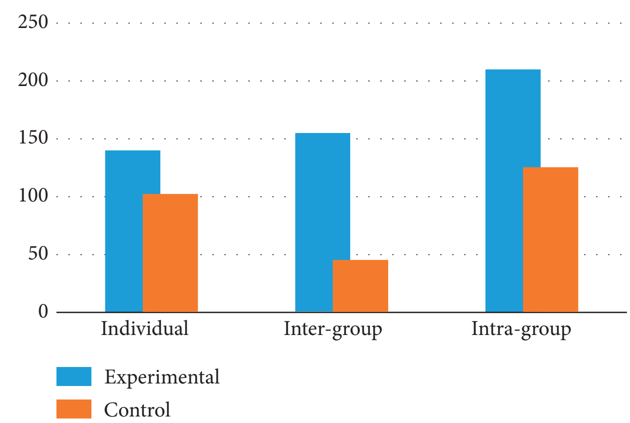

Figure 5: The analysis results of frequency of collective learning behaviors.

5. Conclusion

In conventional approaches, many factors contribute to the problems of inadequate English learning resource management, which delayed system response time and also low user satisfaction. One of the most significant shortcomings of English learners is their inability to accurately grasp the basic daily conversations of fluent English speakers. This article aims to create a web-based English reading learning system to implement administration functions, planned system login, and registration. To accomplish English reading resource integration and resource adaptive recommendation, the feature model and ID3 algorithm are utilized. The testing findings demonstrate that the developed system can meet the predefined functional objectives of English learning resource management and has a quick response time and high user satisfaction. The proposed model indicates that the system has a high application value and will reduce dependency on speculating. Moreover, it can improve learners' capacity to grasp information from the ground up by expanding their understanding of English. In the future study, the number of users should be expanded, and more efforts should be made to improve their learning ability by offering effective and resilient comprehensive reading and active reading techniques.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares no known conflicts of interest or personal relationships that could have appeared to influence the work reported in this paper.

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Research Article

Research on Restoration Algorithm of Tomb Murals Based on Sequential Similarity Detection

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Considering the problems of fuzzy repair and low pixel similarity matching in the repair of existing tomb murals, we propose a novel tomb mural repair algorithm based on sequential similarity detection in this paper. First, we determine the gradient value of tomb mural through second-order Gaussian Laplace operator in LOG edge detection and then reduce the noise in the edge of tomb mural to process a smooth edge of tomb mural. Further, we set the mathematical model to obtain the edge features of tomb murals. To calculate the average gray level of foreground and background under a specific threshold, we use the maximum interclass variance method, which considers the influence of small cracks on the edge of tomb murals and separates the cracks through a connected domain labelling algorithm and open and close operations to complete the edge threshold segmentation. In addition, we use the priority calculation function to determine the damaged tomb mural area, calculate the gradient factor of edge information, obtain the information entropy of different angles, determine the priority of tomb mural image repair, detect the similarity of tomb mural repair pixels with the help of sequential similarity, and complete the tomb mural repair. Experimental results show that our model can effectively repair the edges of the tomb murals and can achieve a high pixel similarity matching degree.

1. Introduction

Ancient murals, as one of China's most important cultural assets, offer a wealth of historical, cultural, and aesthetic information. They serve as an important carrier for China's 5000-year civilisation [1]. The uncovered murals contain several ailments, such as fractures, fading, armoring, and other maladies because of natural weathering and man-made damage. The employment of digital image restoration technologies to help in the conservation of historical murals can minimize the difficulties of protecting ancient murals and the degradation caused by human causes. Cultural relics protection involves both preventative and rescue measures. The rapid expansion of national economic development is accompanied by a significant number of urban facilities. Because valuable cultural artefacts are frequently found, China's principal cultural conservation method is "rescue protection" [2]. To prevent further degradation of cultural treasures that do not satisfy the requirements for on-site conservation, excavation and relocation protection are required. Tomb murals are one of the most well-known examples. Due to the effects of tomb collapse, water erosion, and tomb robber damage, uncovering and relocating murals to other locations for preservation is a better protective method. The environment was generally stable before the mural was removed from the tomb, but after the painting was removed, the storage environment altered drastically compared to the curtain chamber, resulting in a series of pathological issues in the mural [3].

Deformity, displacement, deformation, fracture, crack, armor lifting, falling off, empty drum, caustic soda, mildew, and other issues occur in the preservation of the tomb paintings now housed at the Shaanxi History Museum. The number of tomb murals is vast, the demand for restoration is high, the work is complex, and the actual repair is tough, resulting in a long time between the excavation of most murals and meeting with most tourists [4]. As a result, how to improve the restoration impact of tomb murals has become a major study topic in this discipline, with a lot of work done and some promising results.

Based on the paintings of the Yuan Dynasty Tombs at Hansenzhai, Xi'an, Jiang et al. [5] suggested a digital restoration approach. They examined the damage and types of paintings in Yuan Dynasty tombs in Hansenzhai from the perspective of the degree of image information loss and the link between the loss of information and known information. They also proposed a mural digital repair technique that combines human and automated repair, as well as a mural digital automatic repair algorithm that is based on picture blocks and sparse representation models. Finally, a section of sanletu on the west wall of the Hansenzhai corridor is chosen as a digital restoration example. Different scale discriminators have varying receptive fields that guide the generator by creating a global image view with much finer details. The notion of WGAN (Wasserstein GAN) is utilized to mimic the sample data distribution using EM distance to solve gradient disappearance or gradient explosion in GAN training. The algorithm's network model is trained and evaluated on the CelebA, ImageNet, and place image datasets. The findings demonstrate that, when compared to prior models, the algorithm increases image restoration accuracy, produces more realistic corrected images, and is appropriate for multiple image repair. However, in the process of tomb mural restoration, the algorithm does not evaluate the influence of the actual surroundings on the restored image, which has certain limits.

Tao et al. [6] proposed an image restoration algorithm based on edge features and pixel structure similarity. An adaptive repair template based on information entropy will then fill cracks and bad pixels in the Criminisi algorithm. Finally, the *Drosophila* optimization algorithm is introduced to reduce the image repair time. The experimental results show that the algorithm in this paper can achieve satisfactory repair effect and repair efficiency for different images, but the algorithm is slightly insufficient in processing pixels, which needs to be further strengthened. The experimental results show that the proposed algorithm can achieve satisfactory repair effect and repair efficiency for different images. However, the algorithm is slightly insufficient in processing pixels, which needs further improvements.

In this paper, we propose a tomb mural restoration algorithm based on sequential similarity detection to cope with the aforementioned problems. By determining the gradient value of the tomb mural through the second-order Gaussian Laplace operator in LOG edge detection, we reduce the noise in the edge of the tomb mural and enhance the smoothness of the edge of the tomb mural. Also, we set up the mathematical model of the features of tomb murals to obtain the edge features of tomb murals. The maximum interclass variance method calculates the average gray level of foreground and background under a specific threshold and considers the influence of small cracks on the edge of tomb murals. The cracks are separated by a connected domain labelling algorithm and open and close operations to complete the edge threshold segmentation of tomb murals. The priority calculation function is used to determine the damaged tomb mural area, calculate the gradient factor of edge information, obtain the information entropy of different angles, determine the priority of tomb mural image repair, detect the similarity of tomb mural repair pixels with the help of sequential similarity, and complete the tomb mural repair. Experimental results verify the effectiveness of our proposed method.

2. Research on Edge Feature Extraction and Prethreshold Segmentation of Tomb Murals

2.1. Extraction of Tomb Mural Edge Features. The primary structure of the painting is outlined by the edge of the tomb mural, and removing the edge helps to show the arrangement of the main picture. Because tomb murals are funeral objects, they have the advantages of a quick build time and a big format. Because most of them travel via the drafting line, the painting area is restricted. The primary picture has a clean shape with a lot of iron lines. Two-dimensional information processing technology's edge retrieval approach can identify its contour boundary in advance, which is useful for rapidly comprehending the painting level arrangement. The edge of art can depict the entire objective item, allowing the spectator to quickly find the target. The edge protects detailed image data, which is crucial for determining the object's primary characteristics. Edge retrieval locates the pheromone in the information cluster whose gray value gradient changes abruptly; the gray value varies smoothly along the edge direction and forcefully perpendicular to the edge direction, depending on the features.

In the information cluster, edge retrieval locates the pheromone with a sharp gray value gradient. The gray value varies softly along the edge direction, and the gray value of the pheromone perpendicular to the edge direction changes abruptly until the edge information is located, according to the features. Due to noise and other reasons, the first generated edge information is frequently overconnected or underconnected. There is a requirement for a secondary connection. Different linked domains yield different connection outcomes, and the binary edge information of a single pheromone width may eventually be retrieved. Edge pheromone connectivity consists of two steps: crucial labelling and connection. The pheromones in the linked neighborhood are given a distinct label by labelling [7]. The edge pheromone belongs to the same edge segment when its gray value and direction fulfil the necessary similarity requirements.

To repair the mural image, we can use the gradient operator of the edge pheromone as

$$\nabla I = \begin{bmatrix} g_x \\ g_y \end{bmatrix} = \begin{bmatrix} \dfrac{\partial I}{\partial x} \\ \dfrac{\partial I}{\partial y} \end{bmatrix},$$
$$\begin{cases} M(x, y) = \sqrt{{g_x}^2 + {g_y}^2}, \\ N(x, y) = \tan^{-1}\begin{bmatrix} g_x \\ g_y \end{bmatrix}, \end{cases} \tag{1}$$

where M represents the gray scale while N indicates the gray order jump direction. We utilize LOG edge detection to extract the tomb mural's edge even more precisely. To begin, the second-order Gaussian Laplace operator is employed in LOG edge detection to decrease noise in the tomb mural's edge and deal with the smoothness of the tomb mural's edge [8], as follows:

$$G(x, y) = \frac{1}{2\pi\sigma^2}\exp\left(-\frac{1}{2\pi\sigma^2}\left(x^2 + y^2\right)\right), \tag{2}$$

where parameter σ describes the smoothness of the edge of the tomb chamber. Further, we use the convolution $G(x, y)$ with the tomb mural image $I(x, y)$ to get the smoothness effect of the edge of the final tomb mural image as follows:

$$g(x, y) = I(x, y) \times G(x, y). \tag{3}$$

Similarly, we can obtain the Laplace calculations for $g(x, y)$ as

$$h(x, y) = \nabla^2 (I(x, y) \times G(x, y)). \tag{4}$$

The edge features of tomb murals are extracted by smoothing the edges of tomb murals. The mathematical model for setting the characteristics of tomb murals is as follows:

$$G_\theta = \frac{\partial G}{\partial \theta} = \theta \nabla G, \tag{5}$$

where G represents the normal vectors and θ represents the gradient vector.

Maximum features of tomb mural can be calculated as

$$\gamma(x, y) = \sqrt{E_X^2 + E_Y^2}, \tag{6}$$

where $\gamma(x, y)$ represents the edge feature information of the tomb mural at the x and y points and E represents the corner information of the mural in the tomb.

We can minimize the noise in the edge of tomb paintings and achieve the smoothness of the edge of tomb murals by calculating the gradient value of tomb murals and utilizing the second-order Gaussian Laplace operator in LOG edge detection [9] in the edge feature extraction of tomb murals. It also creates a mathematical model of tomb mural features to obtain tomb mural edge features.

2.2. Edge Threshold Segmentation of Tomb Murals. According to the previously mentioned edge features of tomb murals, thresholding and segmenting the edges of tomb murals is required to increase the repair impact of tomb paintings. Because of the filthy muck on the tomb mural's border, it is impossible to distinguish between the foreground and backdrop. The universal threshold segmentation technique cannot be implemented, despite the fact that histogram equalization improves the crack information. Under a specified threshold, the greatest interclass variance technique determines the average gray level of the foreground and background. When the variance is the greatest, the difference between the foreground and background is regarded to be the greatest.

$$\begin{aligned} g &= w_0 g_0 + w_1 g_1, \\ v &= w_0 (g_0 - g)(g_0 - g) + w_1 (g_1 - g)(g_1 - g), \end{aligned} \tag{7}$$

where g is the total average grayscale of the image, w_0, w_1 represent the proportion of the foreground and background points to the image, respectively, g_0, g_1 represent the average grayscale of the foreground and the background, and v is the variance between the foreground and the background.

Because tomb paintings include stains and numerous small fractures on their edges, these cracks play a major role in tomb mural edge alteration. As a result, before threshold segmentation, it is still important to evaluate the impact of tiny fractures. The tomb mural's crack information is in the form of numerous discontinuous parts, making it hard to separate from the pit [10]; therefore, it is closed to maintain crack continuity. The fractures are then separated using the linked domain labelling method and open and close procedures as

$$\begin{aligned} B(i, j) &= 1, \\ B(i, j) &= A(i, j)\, or\, B(i, j), \end{aligned} \tag{8}$$

where $A(i, j)$ is a pixel value and the updated value of $B(i, j)$ is the result of tomb mural cracks.

The greatest interclass variance technique is used to compute the average gray level of foreground and background under a particular threshold in tomb mural edge threshold segmentation. To finish the edge threshold segmentation of tomb paintings, a linked domain labelling algorithm and open and close operations are used to separate the cracks, taking into account the effect of tiny fractures on the edge of the tomb murals [11].

2.3. Priority Calculation of Tomb Mural Image Restoration. After the above edge threshold segmentation of the tomb mural, the image restoration priority needs to reduce the damage to the disordered tomb mural during the restoration process. The tomb mural image is 1, Ω is the broken pixel area, p is a broken block (size 9×9), and n_p represents the normal vector of the central pixel p of the damaged block; its vertical direction is the smallest direction of gray value (equal illumination line direction). The priority calculation function is defined as

$$P(p) = C(p) \times D(p), \tag{9}$$

where $C(p)$ is the confidence item while $D(p)$ is the data item.

$$\begin{aligned} C(p) &= \frac{\sum_{q\epsilon p} C(q)}{\phi_p}, \\ D(p) &= \frac{\left|\nabla I(1/p) \times n_p\right|}{255}, \end{aligned} \tag{10}$$

where $\sum_{q\epsilon p} C(q)/\varphi_p$ represents the confidence item value of the q pixels in the damaged block φ_p.

Based on this, our model adds the gradient factor G_P reflecting the edge information and the information entropy. H_p measures the complexity of the block to be fixed and G_P represents the gradient information of the image. The final tomb mural image priority can be calculated as

$$G_P = \frac{\sum_{q\in p} M_q}{\left|\phi_p\right|}, \tag{11}$$

where M_q is the gradient modulus of the pixel q and H_p is the derivative of pixel point q in x, y directions.

The damaged area is determined by the priority calculation function in the tomb mural picture repair priority calculation. We may estimate the tomb mural picture restoration priority by calculating the information entropy of different angles using the gradient factor of the edge information.

3. Realizing the Restoration of Tomb Murals Based on Sequential Similarity Detection

The waveform matching continuation technique is a common approach for sequential similarity identification in endpoint effect suppression. The notion behind the method is that the signal's changing trend is reflected not just at the endpoint but also inside the signal, particularly for signals with strong regularity. The unique surgery procedure is divided into two parts:

(1) Finding a subwave segment in the signal that is most consistent with the endpoint's shifting trend.

(2) For continuation, the best-matched wavelet is translated to the endpoint [12].

Because of its strong endpoint effect suppression performance, the method has been frequently employed, particularly in the endpoint effect processing of signals with robust regularity. The key and core of the method is the search technique for the best matching wavelet. To tackle this problem, this study presents an EMD endpoint effect suppression technique based on adaptive sequential similarity detection. Sequential analysis is a mathematical statistician's idea. The sequential sampling system and statistical inference with this scheme are its primary study directions.

The main idea is that in the sampling process, the required number of samples is not determined in advance, but rather a small portion is selected first, and whether or not to continue sampling work is determined based on the results of this small part of samples to effectively reduce the number of samples. Because of its benefits of inexpensive processing and high precision, the sequential similarity detection method [13] is frequently employed in picture matching and other domains. The choice of threshold and the technique for adjusting it are the two most important variables determining its success. As a result, the tomb murals are repaired using the sequential similarity detection approach.

First, when the mural is completed, the original pixel is X. The original pixel point picked must have a maximum point and a low point to better depict the shifting trend of the original pixel restoration at the mural conclusion. To sample the original mural pixel point and produce K sampling points, the longitudinal coordinates are stored as M and m:

$$\operatorname{dir}(p,q) = \frac{p-q}{p-q} \times N(p), \tag{12}$$

where Y represent the original pixel points of the original tomb mural and form several matching points with the original pixel points of the original tomb mural defined as

$$\zeta = \frac{\left(-u_y, u_x\right)}{\sqrt{u_x^2 + u_y^2}}. \tag{13}$$

Similarly, the threshold φ_q of the initial tomb mural image can be calculated as

$$\varphi_q = \arg\min d\left(\varphi_p, \varphi_q\right). \tag{14}$$

The difference between the original point and the counterpart to match is calculated from the first burial chamber mural image pixel point $(x_i - y_i)$and $M - m$ as

$$\left(\frac{(x_i - y_i)}{M - m}\right)^2, \quad i = 1, 2, \ldots, K. \tag{15}$$

According to the determined pixel matching error of the tomb chamber mural image, the sequential similarity detection algorithm successively selects the pixels on the image to be matched as

$$\begin{aligned} I(i,j) &= \left\{\chi \middle| \min\left[\tau\left(i,j,m_k,n_k\right)\right] > T_k\right\}, \\ K[P(S)] &= U(X)\frac{C_4(s)}{[I(i,j)]^2}, \end{aligned} \tag{16}$$

where $K[P(S)]$ represents the real value tomb chamber mural image with mean zero, $U(X)$ represents the probability density function, and $(C_4(s)/[I(i,j)]^2)$ represents the average zero value of the restored tomb room murals [14].

4. Experimental Results

4.1. Experimental Settings. In order to verify the effectiveness of this repair algorithm, an experimental analysis is carried out. In the experiment, some murals in the polo paintings of Prince Zhang Huai and Li Xianmu were used as research objects. In the experiment, the sample images of the tomb murals were 2 m high and 5 m long. The total number of images of the tomb murals collected by HD equipment was about 10 g, which were cut into several small images. The data volume of each image was more than 1G. One of the obtained sample images was taken as a typical research object to verify the effectiveness of the repair algorithm. The experimental sample image is shown in Figure 1.

4.2. Experimental Index Design. To verify the effectiveness of our repair algorithm, we perform experiments with various settings. We undertake tests with various parameters for the validation of the effectiveness of our proposed method. Some of the paintings in the polo paintings of Prince Zhang Huai and Li Xianmu were used as test learning projects. The

Figure 1: Image of the sample tomb room murals.

tomb paintings were 2 m high and 5 m long in the example images. The entire number of photos of the tomb paintings gathered by high-definition equipment was around 10 g, which were then split into many smaller images. Each image has a data capacity of almost 1 GB. One of the generated example photos was used as a specific study object, demonstrating the efficacy of the repair method. Figure 1 depicts an experimental sample picture [15].

Precision, recall, and $F1$ score are three metrics used to assess the accuracy of the classifier's predictions. These metrics are defined as follows:

$$\text{precision} = \frac{\#\text{ of true positives}}{\#\text{ of true positives } + \#\text{ of false positives}},$$
$$\text{recall} = \frac{\#\text{of true positives}}{\#\text{ of true positives } + \#\text{ of false negatives}},$$
$$F_1 \text{ score} = \frac{2}{(1/\text{recall}) + (1/\text{precision})}. \tag{17}$$

4.3. Analysis of Experimental Results. In order to verify the effectiveness of the proposed algorithm, it is compared with the multiscale generation adversarial network image restoration algorithm and the image restoration algorithm based on edge features, and the pixel structure similarity is used to restore the sample tomb mural image. The presentation effect after the repair is shown in Figure 2.

The performance gap between the results obtained from our proposed restoration of the sample tomb mural images method, the multiscale generation countermeasure network image restoration algorithm, and the image restoration algorithm based on edge features can be seen by examining the repair results in Figure 2. The background of the mural picture of the example tomb has some tiny cracks, and the artwork's colour has deteriorated significantly. The image's backdrop effect is smoothed out, and the edge and colour of the tomb mural image may be correctly fixed using this approach. The image restoration algorithms based on edge features and pixel structure similarity, as well as the multiscale generative countermeasure network image restoration method, can eliminate the noise in the tomb mural's wall. The tomb mural pictures restored by the two restoration algorithms, on the other hand, are absent, as are the human cheeks in Figure 2(c).

This method, as well as the multiscale generative countermeasure network image restoration algorithm and the image restoration algorithm based on edge features and pixel structure similarity, is used to match the pixel similarity in the sample tomb mural image in order to further verify the effectiveness of this restoration algorithm. The representative method's effect improves as the matching degree increases. Figure 3 depicts the outcomes of the experiment.

The experimental results in Figure 3 show that there are some differences in the accuracy of matching the pixel similarity in the sample tomb mural image when using the method proposed in this paper, the multiscale generation countermeasure network image restoration algorithm, and the image restoration algorithm based on edge features and pixel structure similarity. The accuracy of matching pixel similarity in the sample tomb mural image by this method is always greater than 80%, with the highest being around 95%, and through multiscale generation to confront the network image restoration algorithm and the image restoration algorithm based on edge features and pixel structure to match the accuracy of the pixel similarity in the sample tomb murals. However, it is always lower than that of the proposed method.

The outcomes of the trained models making predictions on the validation set are summarized in Tables 1 and 2. We can see that the proposed technique works well for both tomb-containing and non-tomb-containing pictures. Interestingly, despite using an enhanced dataset to train SVMs, their performance in recognizing images containing tombs was not comparable to that of the suggested approach. This is unexpected because the tomb forms are mostly basic to the human sight, thus nonlinear classification should function fine. The reason for this is because SVM models are likely to contain a large number of false positives (objects that are not tombs being identified as such). This is because other pictures that are just circular in form are likely to be mistaken for tombs by the SVM models. The number of filters


(a)


(b)


(c)


(d)

Figure 2: Comparison of the repair results of different methods. (a) Sample image. (b) Paper method. (c) Image restoration algorithm of multiscale generative countermeasure network. (d) Image restoration algorithm based on edge features and pixel structure similarity.

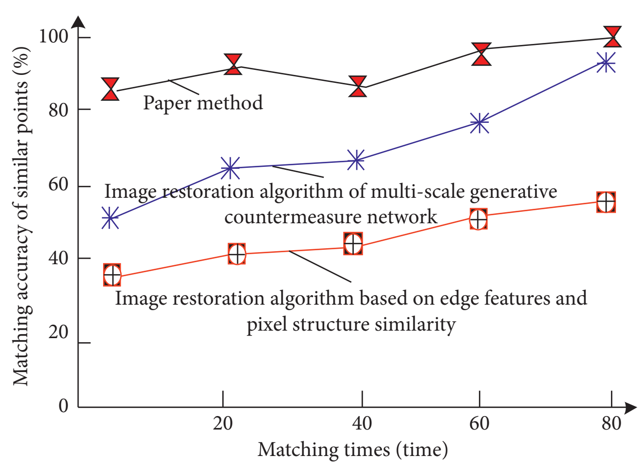

Figure 3: Different methods' analysis of pixel similarity.

Table 1: Different classification metrics to validate the dataset images without tombs.

Model	Precision	Recall	F_1 score
Random guessing	0.64	0.65	0.65
SVM with linear kernel	0.88	0.91	0.90
SVM with RBF kernel	0.92	0.93	0.91
Proposed	0.98	1	0.99

Table 2: Different classification metrics to validate the dataset images with tombs.

Model	Precision	Recall	F_1 score
Random guessing	0.56	0.55	0.56
SVM with linear kernel	0.25	0.134	0.179
SVM with RBF kernel	0.73	0.64	0.68
Proposed	1	0.84	0.91

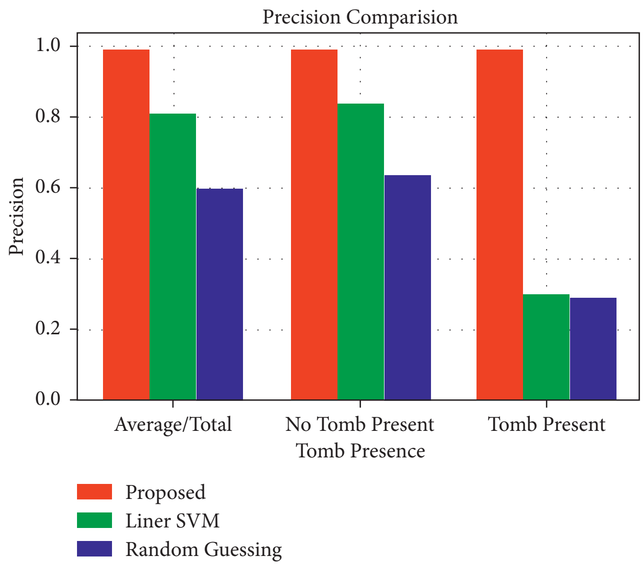

FIGURE 4: Performance comparison for precision.

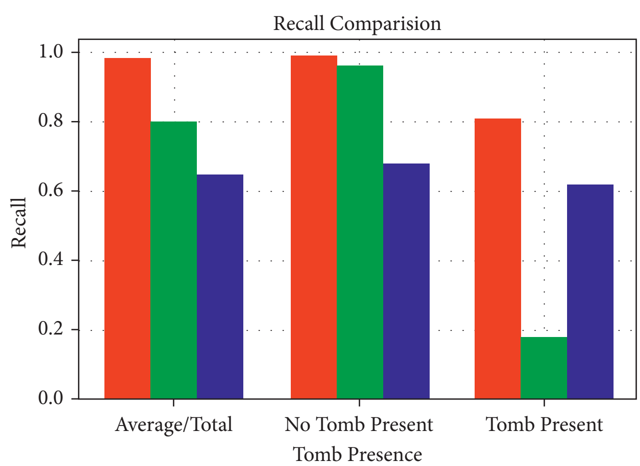

FIGURE 5: Performance comparison for recall.

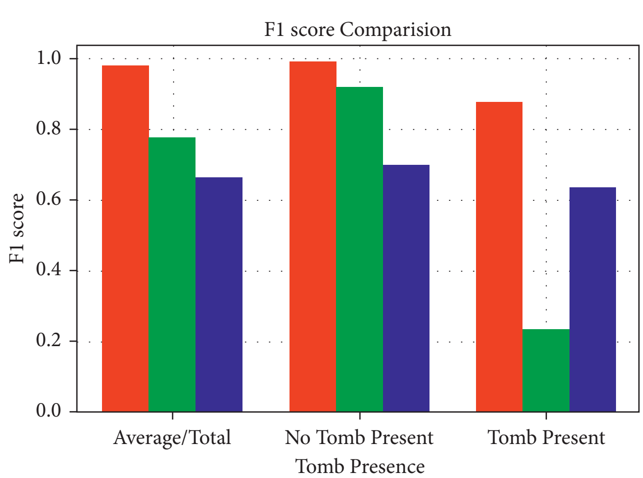

FIGURE 6: Performance comparison for F1 score.

employed in our architecture allows us to notice higher subtlety in the patterns of the training dataset, allowing us to identify a tomb beyond simply the circular form. Figure 4 summarizes both tables and adds an average/total bar with a weighted average for each group. Overall, the findings demonstrate that the proposed model outperforms the competition. Finally, the comparison for recall and F1 score is made in Figures 5 and 6, respectively.

5. Conclusion

We present a tomb mural restoration technique based on sequential similarity detection in this study. By using the second-order Gaussian Laplace operator in LOG edge detection to determine the gradient value of the tomb mural, we can minimize noise in the tomb mural's edge and improve the smoothness of the tomb mural's edge. Then, to get the edge features of tomb paintings, we created a mathematical model of the features of tomb murals. Under a specified threshold, the greatest interclass variance technique determines the average gray level of foreground and background. The fractures are separated using a linked domain labelling method and open and close operations to complete the edge threshold segmentation of tomb paintings, taking into account the effect of tiny cracks on the edge of tomb murals. To identify the damaged tomb mural area, compute the gradient factor of edge information, acquire the entropy of different angles, and determine the tomb wall painting, the priority calculation function is employed. The proposed approach can restore the tomb mural and increase its efficacy, according to the testing results.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Application of Data Mining in Traditional Benchmark Evaluation Model for Buildings Energy Consumption

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Since the beginning of data mining technologies, buildings have become not just energy-intensive but also information-centric. Data mining technologies have been widely used to utilize the huge quantities of buildings' operational data to improve their energy systems. Conventional benchmarking of buildings' energy performance reflects a variety of parameters, such as the number of inhabitants, the environment, the energy efficiency of equipment utilized, and the adjustment of internal temperature. These various elements are then assigned weights to generate a single general indicator. This study presents a reasonable benchmark assessment methodology of conventional buildings' energy usage based on a data-mining algorithm for acquiring more specific information, like the energy management efficacy of a building, and aiming at the problem of ineffective use of large amounts of energy consumption in public buildings. A mathematical-statistical approach and a data-mining tool are used to analyse the data. The degree of connection between numerous influencing variables (i.e., characteristic parameters) and building's energy usage is determined using grey correlation analysis. In this work, we have used an enhanced Apriori algorithm to identify the link between the different forms of systems in the same area. In short, the fundamental idea and process of the Apriori algorithm are presented, and preliminary designs of the preprocessing of experimental data as well as the analysis methods are studied to analyse the outcome of the proposed work.

1. Introduction

Every technological improvement produces a series of products and services as part of the social evolution, but it also leads to a rapid increase in resource and energy consumption. Although a variety of technical developments may improve resource usage and energy efficiency, per capita energy consumption continues to rise. Buildings' energy efficiency is improved by having reasonable demand-side energy consumption, whereas supply-side energy demand is improved by having appropriate supply-side energy consumption [1]. To analyse the rationality of buildings' energy consumption on the demand side, we need to determine the energy wastes component and causes. It is important to explain the energy consumption characteristics of the particular interior environment. This achieves a change from the supply to the demand side in the building's energy-saving mode. The energy consumption of buildings has become increasingly important as the construction industry has risen rapidly in conjunction with urbanization [2–4].

The design and construction industries account for 36% of worldwide final energy consumption and almost 40% of the total direct and indirect carbon dioxide emissions [5]. In the context of future construction management in an urban-based living environment, energy savings may be realized by increasing the dynamical energy efficiency of a building [6]. Moreover, due to the prevalence of smart sensors and the deployment of intelligent building management systems [7], construction activities are data-intensive. A significant quantity of building operational data is gathered to provide a framework for creating performance analysis. As a result, using big data-driven techniques to construct smart energy management is a potential option for addressing energy conservation.

According to [8], the share of energy usage of buildings in the overall energy consumption is increasing steadily, putting enormous strain on energy consumption. The operational waste of buildings is a particularly critical component of energy consumption, accounting for roughly 80% of total energy consumption [9, 10]. Therefore, the only option to establish a resource-conserving society and economic development is to increase knowledge and cognition of buildings' energy conservation. The major challenge for the building sector is how to extract precious data quickly and efficiently from vast data, uncover the problems with using energy consumptions, and enhance the efficient and rational use of buildings' energy.

Traditional Chinese architecture has a complex and varied framework. First, classic architecture is brilliantly constructed which inspires future generations and provides a solid foundation for modern architectures. Furthermore, the traditional architecture allows for natural building ventilation, such as ventilation with pressure differences and ventilation between levels, which improves people's living conditions [11–13]. Traditional architecture requires a lot of climate adaption design. It often depends on the nature of area features, but people's demand for comfortable shelter is also quite strong. The primary goal of the construction industry is to offer pleasant living quarters. Because technology is continuously improving, the construction sector is looking for ways to reduce energy usage. The kind and number of small and large equipment in metropolitan public buildings, as well as data on energy use, are rapidly expanding. A large number of building energy consumption data have been accumulated, with the establishment of an energy consumption monitoring system and the implementation of air conditioning, lighting, power supply, and other items of measurement. The main characteristics of these data are a large amount of data and a large amount of information. Traditional data analysis methods cannot meet the potential value of these incomplete, irregular, and huge data. Data mining can effectively solve such problems. The particular mining process comprises data processing, preprocessing, data mining energy consumption, assessment of results from data information mining, and application of the model. Many other researchers have utilized algorithms like K-means, Chameleon, and DBSCAN to construct an energy-reduction cluster model [14–16]. When applying these methods to the energy consumption clustering of buildings such as buildings, offices, and malls, the distribution of energy and the average value of each cluster can be calculated. Following that, the data are utilized to create an energy conservation evaluation index of buildings. This gives us a scientific and acceptable basis for making building energy conservation decisions. Several data mining approaches may be used for data processing depending on the application areas, user expectations, and application procedures.

Data mining methods have been widely utilized to unlock the values of enormous volumes of building operation data, as the author in [17] worked to improve the operational performance of building energy systems. This study attempts to give a comprehensive review of the applicability of data mining technologies in this industry. In general, there are two types of data mining technologies: supervised data mining and unsupervised data mining. For forecasting building energy load and detecting/diagnosing problems, supervised data mining algorithms are frequently utilized in this industry. The importance of energy-efficient building systems cannot be overstated, given the construction sector's continual development as a significant energy user in the modern world [16]. Today, most buildings have an electric dashboard for recording demand forecasts, which offers several study opportunities by employing this data in energy modelling. This paper investigates standard methods for regression in energy estimation and presents three models with data classifications to improve their performance. Regression methods and an artificial neural network model with data categorization for projecting hourly or hourly energy use in four different buildings are among the recommendation strategies. Energy data from a building energy simulation program as well as existing buildings are collected to develop models for a thorough study.

Figure 1 illustrates the fundamental procedure for the application of data mining in the building industry. After identifying issues and targets, we have gathered the appropriate data and a database. Among other techniques, we have utilized a building management system and field measurement and then our desired database prepared on the obtained data. On this foundation, a data warehouse or data mart is built. The data are then analysed, and the most valuable patterns or rules are determined using the proper data mining technologies. Finally, experts in the building sector can extract the information related to these patterns or principles.

Data mining is a multidisciplinary technology that combines artificial intelligence, machine learning, data visualization, and other modern technology to retrieve different algorithms from a large, irregular, complex database using cluster analysis, preliminary analysis, correlation analysis, and other methods to find information that has potential value. Data mining technology has the characteristics of mass and relativity, which can effectively solve the effective classification and information mining of a large number of data and has given full play to its advantages in many fields. For example, on the Internet, IT industry, data mining technology can help the industry realize efficient processing of large-scale e-commerce data, obtain valuable results for enterprises, help enterprises make scientific and correct marketing decisions, and finally achieve accurate push and marketing. The application of data mining in the field of building HVAC is mainly divided into data mining framework process, preprocessing and specific application, etc. Presently, it mostly entails the analysis of building energy consumption data, problem diagnosis and detection, and system and data operation and control optimization, among other things. In construction management, the existing building energy management and automatic control system, which can store a lot of construction operation data,

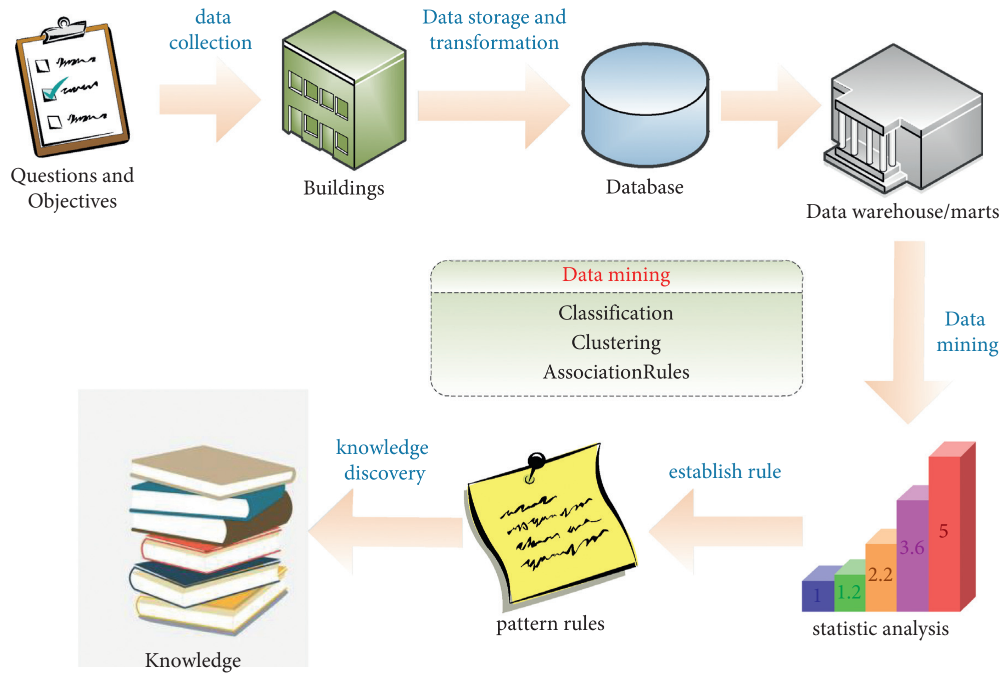

FIGURE 1: The basic process of data mining application in the field of construction.

provide data basis for the research in this field and foundation. The fusion of data mining technology is to provide computational tools and methods for research, by using data mining technology, unearth the operation law of the HVAC system, and promote the progress of research and scientific development. As mentioned in Section 2, various literature evaluations on the uses of data mining techniques in the area of buildings have been published in the last decade. Yet, in the realm of building energy systems, thorough literature evaluations on data mining methods used for load forecast, fault detection/diagnosis, and pattern recognition are still lacking. It is critical to review the findings of past studies and identify potential areas for future study. The main contributions of the proposed work are listed as follows:

(1) Firstly, this work proposed a strategy for addressing the efficacy of traditional building energy throughout the household building process by using a benchmark evaluation approach. Here we optimized the planning and run a clustering algorithm on the overall data.

(2) Secondly, we used three-dimensional (3D) rendering technique to develop a dynamical data analysis model for energy control. Besides, we have used the system for the adaptation construction of traditional building energy.

(3) Thirdly, data mining methods have been widely utilized to identify actual values of huge quantities of building information, in order to improve the overall performance of building energy systems.

(4) Finally, different evaluation methods are used to confirm that the data are evaluated using a mathematical statistics technique and a data-mining algorithm in order to improve the building energy systems.

The remainder of the paper is organised as follows: Section 2 shows a review of relevant work; Section 3 shows our benchmark evaluation model and an enhanced data mining algorithm; and Section 4 shows results obtained and discussion. Finally, Section 5 of our paper brings us to a conclusion.

2. Related Work

Identifying hidden energy consumption features in energy consumption data is a critical step in achieving building energy savings. The association mining analysis technique is used to analyse a large number of building energy consumption data, using a simple and progressive analysis procedure. Relevant scholars utilized the Apriori algorithm mining method to build strong association rules, from which they discovered the air conditioning system's unreasonable operational problems before and after the noon break. Then, targeted improvement measures were taken to improve the operating efficiency of the air conditioning system, achieve effective energy saving in building air conditioning, and promote the pace of building energy construction. The building energy consumption benchmark can be determined by comparing it with other buildings of the same type or with the energy consumption of its own history [18].

Many authors have performed depth research on it, and the three primary evaluation tools are as follows: constructing a score evaluation method, a simulation analysis method, and a statistical analysis method are all methods that may be used to evaluate a score [19]. For example, literature [20] and literature [21] respectively used cluster analysis to classify commercial buildings and hotel buildings. This method can classify buildings by considering the shadow response theory of multiple characteristic parameters on energy consumption at the same time. However, its main limitation is that the influence of different characteristic parameters on classification is ignored, and it is simply treated as the same, which will inevitably lead to a large error of classification results. In addition, residential buildings were not involved in the above research. Considering the particularity of the composition and influencing factors of residential building energy consumption, it is necessary to conduct a separate study on the benchmark evaluation method. At present, many scholars have developed a large number of research works on energy consumption anomaly measurement.

The authors in [22] proposed a real-time monitoring method of building energy consumption based on data mining technology. By combining the DBSCAN algorithm with the classification method, the building consumption value was extracted by category and the new generation energy consumption value was identified as the category, to judge whether it was an abnormal value. Bourdeau [23] improves the modified Z-score algorithm based on GESD, which can reflect the dispersion degree of outlier data while detecting outliers and is suitable for the detection of building energy consumption data. Although these methods can detect the abnormal building energy consumption data, when the spatial density distribution of samples is not uniform or the class spacing is very different, the detection results will show deviation, and the energy consumption data cannot be processed quickly [24].

To summarise, when building equipment and energy consumption increase, data on building energy consumption must be quantified. The key development direction that the construction industry has to pay attention to is how to utilize data mining technology to find valuable data information from large-scale data and give data reference for building energy conservation. The application of data mining technologies in building energy saving will become more prevalent as the technology advances. Inspired from the work of above, this research work presents an evaluation model for building energy consumption based on traditional benchmark.

3. Traditional Benchmark Evaluation Model of Building Energy Consumption

3.1. Determination of Subitem Energy Consumption Benchmark. In this section, in certain circumstances, the energy consumption index values for each unit area of the building obtained through calculation and analysis are determined, but the distribution of energy consumption of each building is reasonable given the reasonable definition of the conditions of use in the research process. Building energy consumption levels may be fairly managed using the energy consumption index per unit area to satisfy the purpose of building service. Based on the index of energy consumption per unit area, at the same time, the average level is determined by fractal levels at 25 percent, 50 percent, and 75 percent. As a result, the related median is chosen as the energy consumption base value in addition to the overall building energy consumption. Figure 2 depicts the energy-saving ratio derived using energy consumption simulation, as well as the associated score.

Because a building's total energy consumption comprises total electricity, total heat, total gas, and different subenergy consumption, the overall energy consumption of a structure is rather high. There are several contributing elements, and mining characteristic data and constructing a model from a large number of building energy consumption data is simple. The grading end performance assessment technique of calculating a building's energy consumption uses the grading evaluation method and examines the data provided by each grade in a step-by-step manner. Building's energy consumption assessment approach is used extensively in green building assessment systems [25].

The energy benchmark of office buildings requires a benchmark model and data processing to be determined. The following equation is the office building model of multiple linear regressions:

$$EUI = \beta_0 + \beta_1 x_1 + \beta_2 x_2^2 + \beta_2 x_2^2 + \cdots + \beta_k x_k^k, \tag{1}$$

where β_0 is regression constant and Ri denotes the regression coefficient.

The data will be initially screened and the viability of the regression model may be confirmed by ANOVA, multiple correlation coefficients (R), etc., depending on the actual circumstances of the sample data. Among these, variance analysis is also known as variance analysis and F-test analysis. The aim is to determine if the total average of two or more data groups is equal or not and to assess whether there is statistically significant or nonstatistical differentiation of two or more sample media. Thus, R is referred to as a multivariate coefficient of correlation:

$$R^2 = \frac{\sum (\hat{y} - y_0)^2 - \overline{y}}{\sum (y - y_0)^2 - \overline{y}}, \tag{2}$$

where R^2 is the efficiency of the model and the summarised regression is shown in Figure 3. Through a comparative analysis of benchmark energy usage, the building owner or management will understand how the building functions and analyse the energy consumption difference between the building and other comparable structures. If the energy consumption of similar buildings is determined to be greater, appropriate actions can be made to minimize the energy consumption.

The appropriate variables were defined using the same technique. As indicated in Table 1, $X1$ represents the building area (numerical variable), $X2$ represents the end form of air conditioning, $X3$ represents the kind of heat source, $X4$ represents the type of cold source, $X5$ represents the type of glass, and $X6$ represents the building structure.

3.2. Traditional Buildings Energy Consumption System. The energy consumption system consists largely of many linked energy consumption devices. During the inquiry process, data from the direct and indirect components of the energy consumption system are gathered. General status of

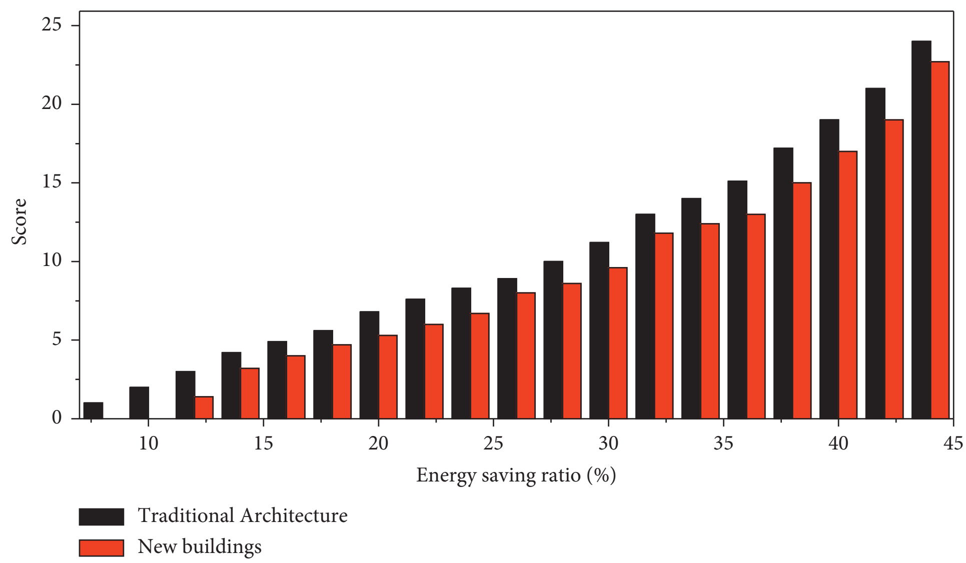

FIGURE 2: Energy-saving ratio and corresponding score.

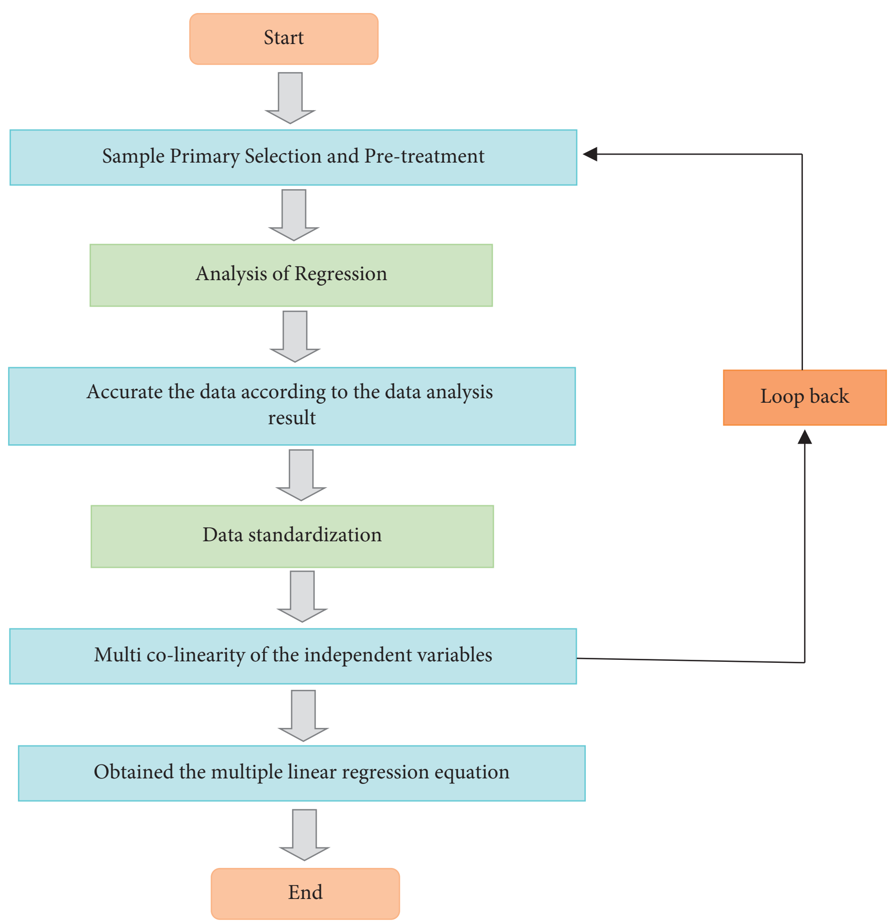

FIGURE 3: Flowchart of regression calculation.

the general details, structure of buildings of palisades, composition of the retaining structures, information on the energy use of the equipment (including air conditioning, lights, and other power equipment) and operating status of the buildings, total annual energy, electricity, energy from month to month, and management data are carefully examined. The acquired data were examined using the mathematical statistics approach. Figure 4 depicts an office

Table 1: Variable number definition.

S no.	Air conditioning end from X2	Heat source from X3	Cool source from X3	Type of glass
1	Fan coil	Municipal water	Water chilling unit	Low-e glass
2	Radiator	Ground source heat pump	Ground source heat pump	General coated glass
3	Cold runner	Direct-fired machine	Direct-fired machine	Common glass
4	Automatic wind	—	—	—

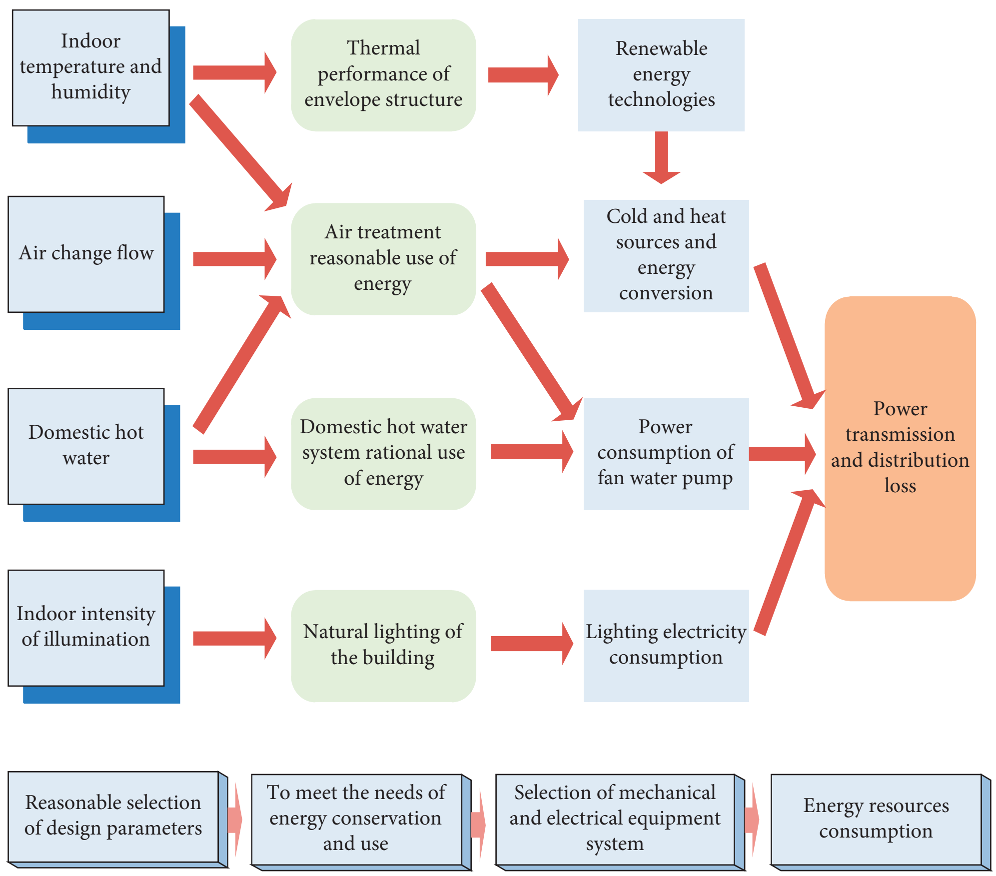

Figure 4: The main energy flow of an office building.

building's primary energy consumption process. Electric electricity, natural gas, heat, and steam, among other energy sources, are utilized by the structure.

Solar photovoltaic systems and photo-thermal systems are the most common forms of renewable energy. Solar energy systems are used in 8 buildings, with 32 percent of those installed after 2005. Only three of the eight buildings employ both photovoltaic and photo-thermal systems at the same time, with the remainder relying solely on photo-thermal. It can be observed that the overall solar energy usage ratio is low, and the photovoltaic system utilization ratio is much worse. Whether the building energy consumption level can be effectively analysed mainly depends on the availability of basic building information and the accuracy and completeness of continuous energy consumption data. The operational data of the system and equipment of the selected study samples are given by property management and energy firms or collected by on-site real-time measurement and transcription. In addition, the effective energy consumption in the data only comprises the energy consumed by the structure to maintain its function, omitting the power, gas, and water consumed by the kitchen or special room.

3.3. Data Mining Algorithm. Cluster analysis rules mining associations and decision tree techniques are the most used approaches for data mining. The two first are used mostly for descriptive data mining, the last being used for predictive data mining purposes. In this article, an algorithm for association regulation mining is mostly utilized. The transaction database is the topic of the common association rules for mining, whereas the training dataset is the subject of a benchmark assessment of building energy use. Because the parameters in the database have varying generalities, it is difficult to relate the row comparison and analysis to them. It is tough to connect the two if the air conditioning operational status is a classification property (on or off) and the building surface product is a numerical value attribute.

The multiple states of multivariate variables, such as the four LEED certification grades for green construction in the United States (certification, silver, gold, and platinum), must be sorted and transformed to the interval [0, 1] according to

$$x_i = \frac{\text{rank}_i - x_0}{\text{rank}_{\max} - x_0}, \tag{3}$$

where x_i is the transition value of a certain state; rank_i is the sorted value of the state; $\text{rank}_{\max}$ is the maximum sorted value for all states. Calculate the grey correlation degree γ of y_0 and y_i, and the calculation equation is

$$\gamma(y_0, y_i) = \frac{1}{n}\sum_{k=1}^{n}\left[\xi_i(k) - y_0\right]^2,$$
$$\xi i(k) = \frac{\min_k \min_i \left|y_i(k) - 1\right| - \alpha \min_k \min_i \left|y_i(k) - 1\right|}{\alpha \min_k \min_i \left|y_i(k) - y_0(k)\right| + y_0(k)}. \tag{4}$$

The grey correlation order of each variable is obtained by sorting according to the grey correlation degree.

3.4. Decision Tree. A decision tree is a supervised learning method that can handle both discrete and continuous data [26]. It divides the dataset into subgroups based on the dataset's most important attribute. The algorithms determine how the decision tree recognizes and divides this characteristic. The most important predictor is the root node, which is divided into decision nodes and terminal or leaf nodes that do not divide further. In the decision tree, the dataset is divided into homogenous and nonoverlapping areas. It employs a top-down method, with the top area showing all of the observations in one location before separating into two or more branches, each of which then splits further. This strategy is also regarded as a greedy approach since it just analyses the current node between the worked on without focusing on the future nodes:

(1) Produce a decision tree from the training tuples of data divider D
(2) Data divider, D, which is a set of training tuples and their related class labels
(3) *attribute_list,* the set of candidate attributes

Our proposed attribute selection approach determines the splitting criterion that best divides the data tuples into separate classes. This criterion includes attribute splitting as well as the possibility of a split point. Algorithm 1 shows the phases of our recommended Decision Tree algorithm after splitting the subset.

3.5. Association Rule Mining Algorithm. An association rule is a form of inference statement: $X \longrightarrow Y$, with being disjoint item-sets: $X \cap Y = \varnothing$. The strength of an association may be determined by the amount of support and faith it has. Support determines the frequency with which a rule applies to a certain data collection, but confidence determines the frequency with which items in Y appear in transactions containing X [27]. These metrics can be seen in equation (5) and in equation (6):

$$\text{Support}, s(X \longrightarrow Y) = \frac{\alpha(X \cup Y)}{N}, \tag{5}$$

$$\text{Confidence}, c(X \longrightarrow Y) = \frac{\alpha(X \cup Y)}{\alpha(X)}. \tag{6}$$

3.6. Apriori Algorithm. Association rules are the most frequent data mining technique. The Apriori algorithm is a well-known method for mining association rules. Many strategies have been developed concerning the rules of mining associations and associated mutations, which depend on the Apriori algorithm. The huge quantity of candidate 2 item-sets and the inefficiency with which they are tallied are the two obstacles of frequent item-sets mining. One superfluous C2 pruning operation is eliminated using the suggested method. If the number of frequently 1item-sets is n and pruning operations are Cn, the number of linked candidate 2 item-sets is Cn. Candidate 2 item-set pruning procedures are reduced using the recommended approach, saving time, and increasing efficiency. The suggested technique leverages the transaction tag to improve subset operations and speed up support computations, which addresses the bottleneck of inefficient support counts. Algorithm 2 shows the phases of our recommended Decision Tree algorithm.

4. Results and Discussion

This portion of the article covers the experiments conducted and the simulation findings produced by the research. Many simulation tests on traditional building energy usage were conducted using an improved Apriori algorithm and a combined decision tree procedure. For household use, we have designed a model to save energy. The classification of traditional building energy consumption has a set of requirements (laptop computer) that can be seen in Table 2.

4.1. Characteristics of Total and Subitem Energy Consumption of Traditional Buildings. To determine the energy consumption value of building reference, information may be provided by analysing and comparing the features of overall energy consumption and the subenergy consumption of homes in traditional structures. It may also better comprehend the energy use of buildings and their energy-saving potential and clarify the emphasis of home saving energy. The average total yearly energy usage of four major household types and the proportions of each kind of home are shown in Figure 5.

The above figure shows that homes in Category 1 have the greatest overall average energy usage, whilst those in category 3 have the least. Of the eight categories of electricity consumed heating, air conditioning, and hot household water, the total energy consumptions of the four types of households account for over 20 percent and the total of two

(1) Make a node N;
(2) If all of the tuples in D belong to the same class, C then;
(3) N will be returned as a leaf node with the class C;
(4) if *attribut_list* is unfilled then;
(5) return *N* by way of a leaf node categorized with the majority class in *D*;//majority elective
(6) apply attribute_selection_method (*D, attribut_list*) to discovery the finest *splitting_criterion;*
(7) tag node *N* with *splitting_criterion;*
(8) if *splitting_attribute* is discrete-valued then;//not limited to binary-trees
(9) *attribut_list* ← *attribut_list - splitting_attribute;*//eliminate splitting_attribute
(10) for each outcomes *j* of *splitting_criterion*
//divider the tuples and produce sub-trees for each divider
(11) let D_j be the set of data tuples in *D* filling the results *j*;//a divider
(12) if D_j is unfilled then;
(13) assign a leaf labeled with the majority class in *D* to node *N*;
(14) else assign the node returned by Generate_Decision_tree (D_j, *attribut_list*) to node *N*;
end for
(15) return *N*;

ALGORITHM 1: Decision Tree.

(1) $K = 1$
(2) Fk = {i $|i$ ε I ˆ σ ({i}) ≥ N ∗ min sup}
{Find all frequent 1 item-sets}
(3) Repeat
(4) $k = k + 1$
(5) CK = Apriori-gen (Fk + 1)
{Make candidate items}
(6) for each transaction t ε T do
(7) Ct = subset (Ck, t)
(8) {Identify all candidates that fit to t}
(9) for each candidate item-set
(10) c ε Ct do
(11) σ (c) = σ (c) + 1
{Increase support count}
(12) end for
(13) end for

ALGORITHM 2: An improved Apriori algorithm for mining association rules.

for over 60 percent. Consequently, they are "large customers", and they should be the emphasis for the conservation of home energy. Among the remaining 6 categories of energy consumption, lighting, kitchen, and refrigeration accounted for a relatively large proportion (the third category of household lighting energy consumption is the smallest and lower than other terminal energy consumption, which may be due to their strong awareness of energy saving and the use of energy-saving lamps in lighting equipment). The energy consumption of lighting and the kitchen, in addition to refrigerators, varies substantially amongst houses. This is because refrigeration equipment runs constantly for long periods and is less affected by user behavior.

Figure 5 further shows that despite having the lowest outside annual average temperature and the highest wind speed, Category 1 households consume substantially less heating energy than Category 4 households. One reason might be that their enclosure construction provides superior heat insulation. The number of homes has a significant impact on the amount of hot water energy used in the household. It is difficult to assume that the greatest number of homes will always result in the greatest residential hot water energy usage (for example, Category 4 has the largest number of households, but not the highest domestic hot water energy consumption).

Figure 6 shows the cumulative frequency distribution curve of the total energy consumption of building, heating, conditioning, and domestic hot water of Category 1 households. The energy consumption values corresponding to the cumulative frequency of 50% and 25% are taken as the reference value and target value. As can be seen from Figure 6, the base value of Category 1 household TEC is 391 MJ/m2/year and the nominal value is 305 MJ/m2/year. Subitem energy consumption index values for households may be calculated by using the cumulative frequency distribution curves of HC and HWS. If the baseline for the same sample is 50 percent of the water level, therefore the results are 111 MJ/m2/year and 127 MJ/m2/year. In the same way, the TEC reference and target values of the other three categories of households can be obtained.

Table 2: Hardware requirements for the experimental work.

S No	Requirements	Specification
1	System core	Core-i7
2	Generation	3^{rd}
3	CPU	2.9 GHz
4	RAM	16 GB
5	Hard drive	ITB
6	Operating system	Windows 10, 64 bits

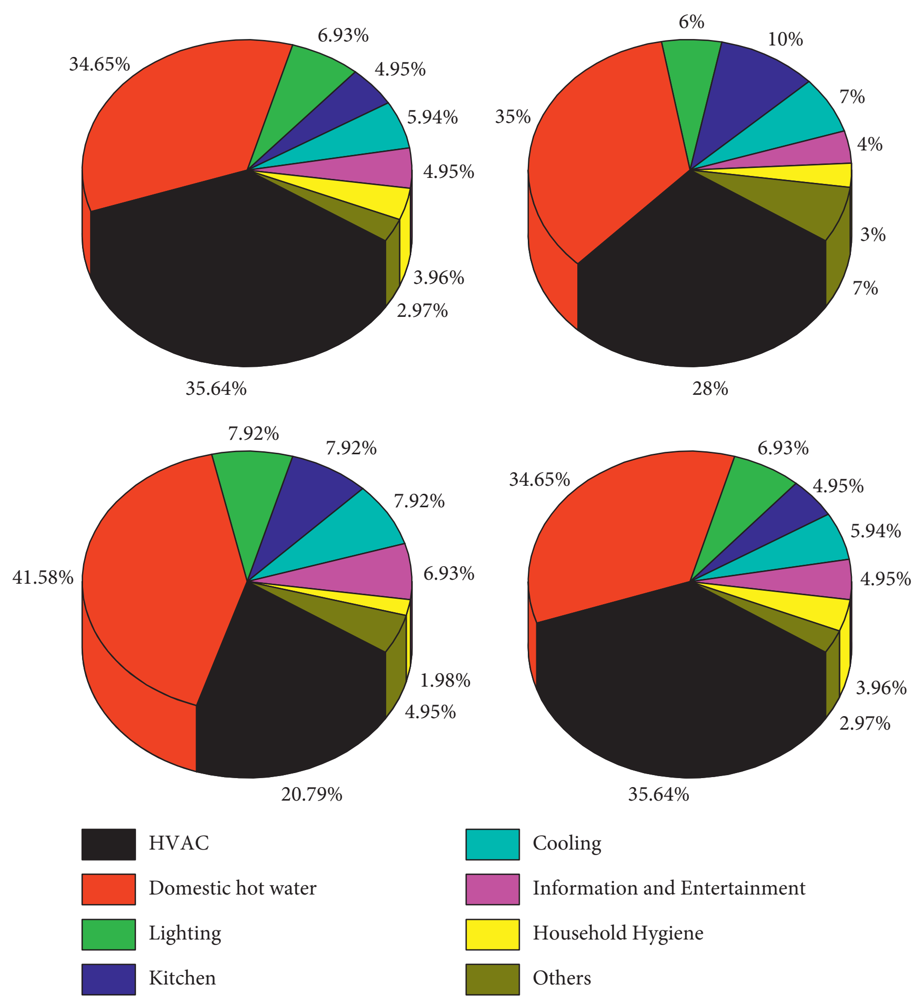

Figure 5: Energy consumption characteristics of 4 types of households.

4.2. Overall Evaluation of Building Energy Consumption. The household with the lowest energy usage and the most similar features to the household can be contrasted with similar homes (the similarity of the characteristics of the two households indicates that the two households have the most comparable reference value based on all characteristic parameters). The distance between the two may be used to symbolize their resemblance; the smaller the gap, the higher the similarity. For instance, the energy use evaluation of A in the first category of households is carried out. By calculating the similarity between other households and A, it can be seen that B is the household with the most similar characteristics. The detailed characteristic parameters (T (Total energy expenditure), WS (Watt Second), RH (Relative Humidity), RA (Resource Adequacy), HLC (Heat Loss Coefficient), ELA (Electrical Load Analysis), and HT (High Tension)) of the two households are shown in Table 3.

In increasing order, Figure 7 depicts the total energy use of all buildings in Category 1 households. As seen in this figure, House A consumes more energy than the baseline, and a structure that consumes a lot of energy is classified as a "nonenergy-saving building". House B consumes less energy than the goal value; therefore, a structure with low energy consumption qualifies as an outstanding "energy-saving building". A household's annual energy-saving potential is 548–391 = 157 MJ/m2 compared to the base value of energy

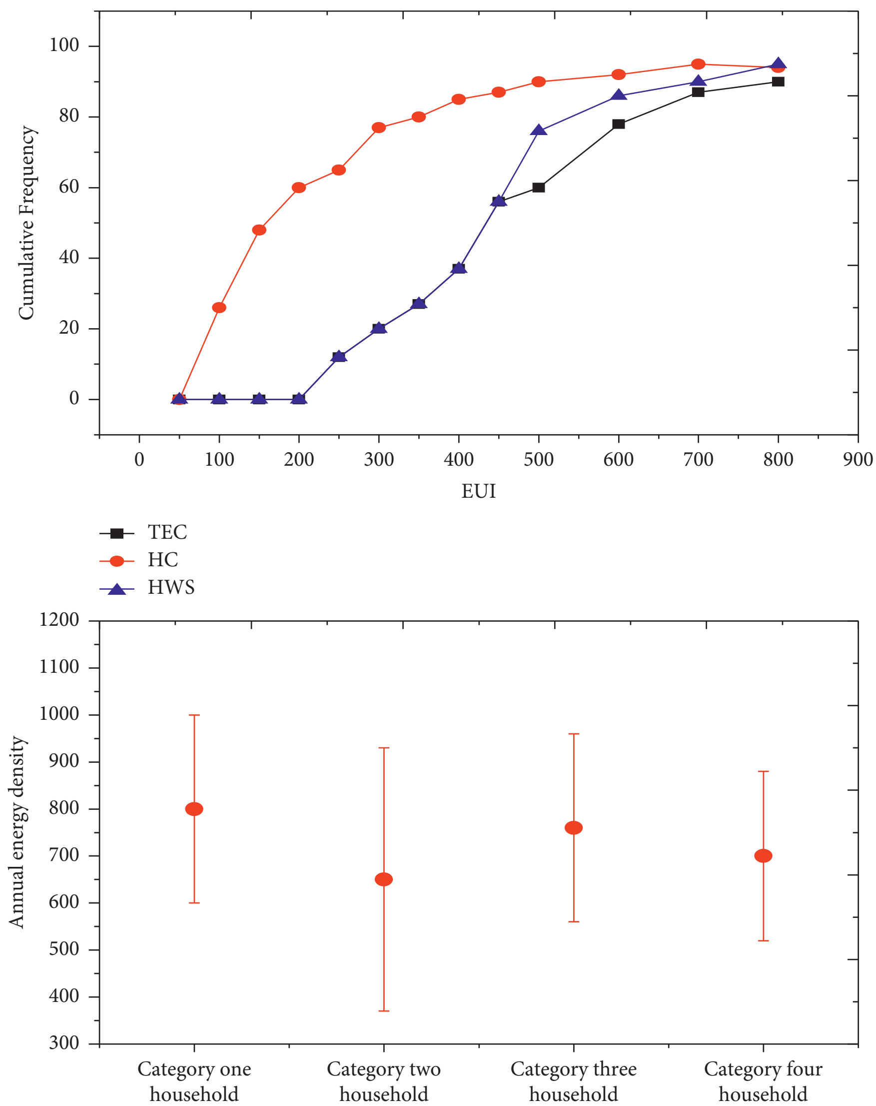

FIGURE 6: The cumulative frequency distribution curve of total energy consumption.

consumption; household B's annual energy-saving potential is 548–304 = 244 MJ/m2. When the building features of the two households are compared, it can be seen that the heat loss coefficient and equivalent leakage area of the envelope structure are significantly different, which might be one of the causes for the first household's high energy consumption. Consequently, through energy-saving transformation, a home may reduce building energy consumption by enhancing the thermal insulation performance of the outer structure and the airtightness of doors and windows.

4.3. Abnormal Detections of Energy Consumption of Traditional Buildings. This paper uses daily itemized energy consumption data (air conditioning and lighting) from a shopping center in the second quarter of 2020 (i.e., June to August, a total of 92 days) to perform irregular and practical testing on the data. Figure 8 shows the energy usage of air conditioning and lights. Before the actual test, we have analysed the energy consumption data used in our experimental work. This is because data from the direct connection source frequently are incomplete and inconsistent and may have a significant impact on the effect of data excavation. To ensure the accuracy and reliability of data, the precanalization of energy data consumption is necessary for the experiment.

The line chart of electricity consumption data obtained after marking the abnormal energy consumption is based on the abnormal detection results (in which the triangular and rhomboid marks represent the detected abnormal energy consumption data and uncertain data of air conditioning electricity, respectively). The round and square marks, respectively, reflect anomalous energy usage data and questionable lighting data that have been discovered. Through the abnormal energy consumption detection model of the MP algorithm, the abnormal value in the data of building energy consumption can effectively be detected and obtained. This can provide necessary help for the management and operation of the construction energy consumption monitoring system.

Table 3: Characteristic parameters of households A and B.

Household	T	WS	RH	RA	NO	HLC	ELA	HT
A	9.0	4.2	70	13.1	3	3.08	0.99	0
B	8.9	4.0	62	11.1	3	2.30	0.87	0

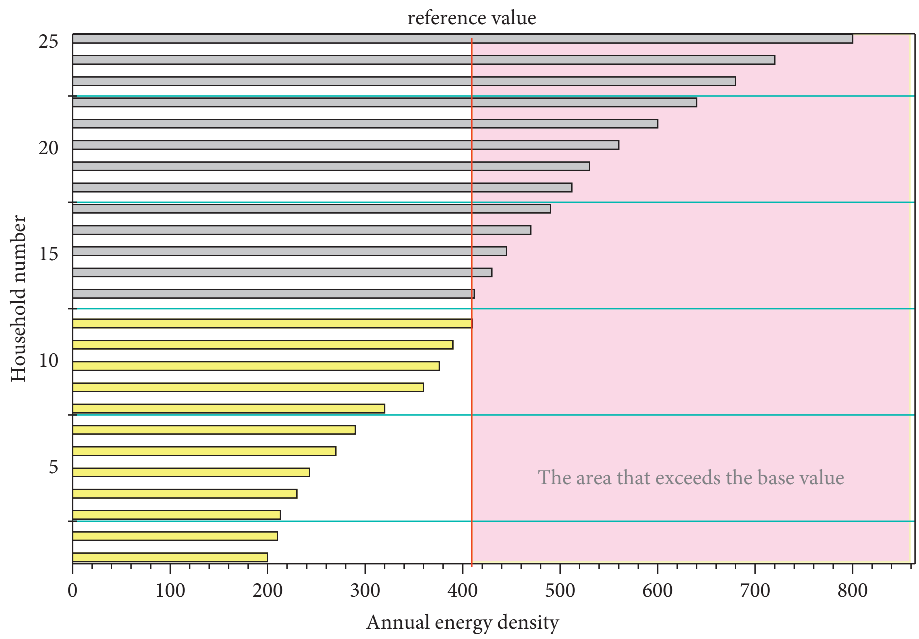

Figure 7: Total building energy consumption of Category 1 households.

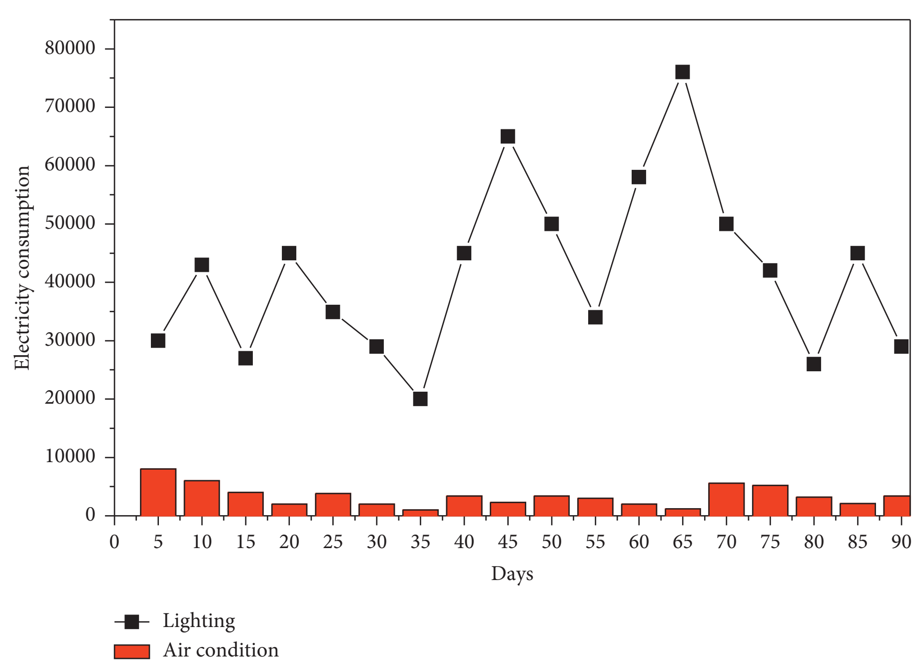

Figure 8: Data of itemized energy consumption (electricity consumption for air conditioning and lighting) of shopping malls in the second quarter of 2020.

Figure 9 illustrates the comparisons of parameters used for household A and household B. The total energy expenditure (T) and High Tension (HT) of both the households are the same. However, the Watt Second (WS), Relative Humidity (RH), Resource Adequacy (RA), Heat Loss Coefficient (HLC), and Electrical Load Analysis (ELA) of household A are 0.2, 8, 2, 0.78, and 0.12, respectively, greater than those of household B.

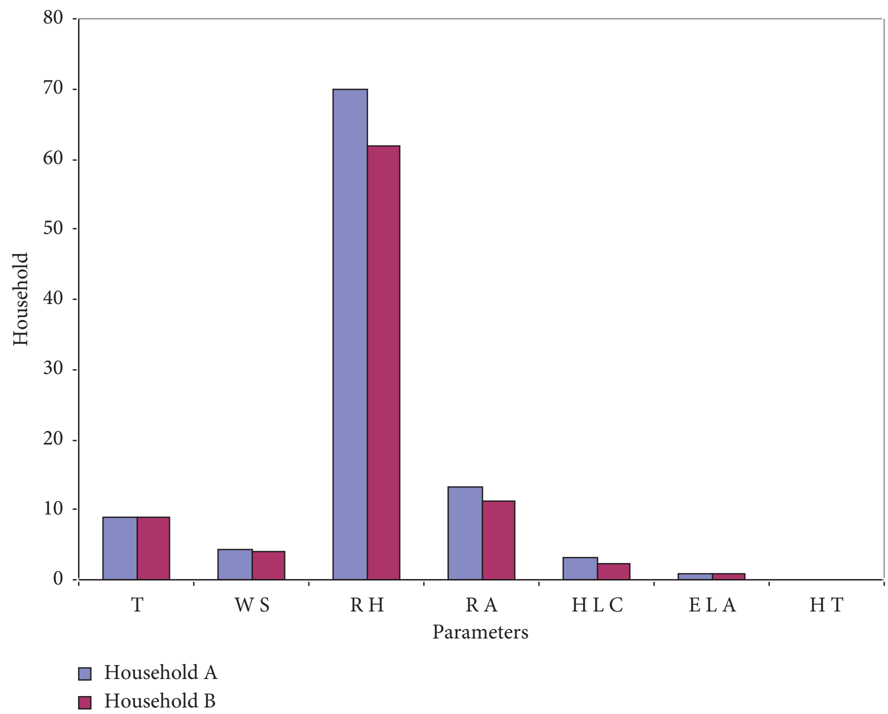

Figure 9: Comparison of household A and household B.

5. Conclusion

In this paper, the traditional buildings are classified, and the building energy consumption reference value is determined and evaluated using data mining techniques. The classification of buildings may be fine-tuned with this technique, and the efficiency of building energy consumption reference values can be enhanced. At the same time, a realistic assessment of a building's energy consumption level requires that the structures being compared have a high degree of similarity. The benchmark energy consumption evaluation method proposed in this paper uses grey correlation analysis to determine the degree of correlation between different influencing factors and building energy consumption then uses the correlation degree as the weight of the factors to classify buildings reasonably using cluster analysis. Our proposed approach can evaluate a typical household energy consumption characteristics and energy-saving potential and also make energy-saving recommendations. The reliability of the energy-saving potential obtained and the feasibility of energy-saving recommendations are both high when comparing and evaluating houses whose energy consumption is lower than the base value and whose characteristics are most comparable to those of households in the same category. While evaluating the benchmark energy consumption, this approach may give a lot of information on building energy efficiency.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this study.

Acknowledgments

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Retraction

Retracted: A College Music Teaching System Designed Based on Android Platform

Scientific Programming

Received 29 August 2023; Accepted 29 August 2023; Published 30 August 2023

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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Research Article

A College Music Teaching System Designed Based on Android Platform

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Today's rapid evolution in information and communication technologies affects all sectors, including education, and has a positive impact. As a result, teachers need to use technology effectively and keep up with innovation to meet the needs of the next generation. The college music educational system was always an important part of higher education in China, and the corresponding music curriculum system has gradually been established. This curriculum system has been instrumental in the systematization and standardization of China's music industry, and it has produced a large number of outstanding musical talents for the country. The goal of this research is to discover advanced and dependable teaching methods. With the growing popularity of mobile intelligent terminal devices and the expanding application of the Android platform, using a mobile intelligent terminal for university courses' learning has become a more powerful technical feature. Through the development of an intelligent learning application using the Android intelligent platform, students can practice exercises and evaluate themselves, allowing them to analyze their weak points based on their evaluation value, whether in class or after class, and then facilitate their learning. In this paper, I present my original perspectives and proposals on music education in colleges and universities, based on literature, analysis, and study, as well as my years of practical experience. To assure stability of the suggested framework, scalability, and sustainability, I have used the Model View Controller (MVC) architecture. This framework is based on the mobile client of Android that teaches and queries college music remotely and controls smart music. According to the experimental data, online music teaching has a greater learning effect on music skills and enhances traditional music performance by 25%. In terms of increasing interest in musical courses, this online college teaching information platform has the ability to raise 74% of students' awareness.

1. Introduction

Information technologies have gained significance in education during the previous century and have attained a lot of attention [1]. Continuous technological advancements have created resources that can be used in educational settings. They have also compelled changes in the teacher profile and role, as well as teaching methods. With the advancement of information technology, the teacher's role has evolved to facilitate learning [2]. As a result, teachers need to use technology effectively and keep up with innovation to meet the needs of the next generation. The theory of online learning was first proposed in the United Kingdom among European and American countries. David Seward proposed the concept of an online learning assistance system in the 1970s, and it has had a far-reaching impact to this day. In response to this idea, foreign education institutions and software vendors have created a range of network learning systems in the past few years, but their basic design patterns are based on utilizing computer multimedia technology, such as video, audio, and other forms of multimedia for learners to impart knowledge, usually through desktop systems and data CDs. In the early 2000s, with the rise of Internet streaming media technology, the online learning system attained unprecedented development through streaming. Here, the learners do not need to complete the download courseware and learning materials, but only need to complete the online learning resources under the limited bandwidth of real-time playback. The learners can choose a section of learning content, which greatly improved the maneuverability and convenience of learning. Nowadays, playing network learning resources are no longer a problem in the context of bandwidth, and there is usually no playing lag. Hence, learning courseware is progressing towards high definition and high quality at this level.

With the rapid advancement of computer technology, the information network has emerged as a critical component of social progress. The goals of current educators are to realize knowledge transfer quickly, efficiently, and conveniently using the network as the link and to promote teaching reform through modern means and transform traditional classroom teaching into classroom, computer, network classroom, Internet, and other learning methods [3]. With its roots in the network teaching environment of modern distance learning, network education is the advanced technological technology applied in the production of a new educational form. The implementation of network education is the key to creating a network environment that can promote learners' active learning.

The development of China's online education support platform has mainly experienced five stages which can be explained in Figure 1.

Although China's research on a network local education platform began late, with the maturation of the concept of network teaching, the construction of network teaching platforms has gradually improved. Network teaching platforms are an effective solution to the contradiction between China's educational needs and resources, and they will become an important direction of China's future educational development. On the contrary, there are still a lot of flaws. For example, research has revealed that the current level of network teaching platforms is unequal and that certain teaching websites contain some unsatisfactory areas. Some even make teaching errors; others have technical issues, and so on. Second, some teaching websites do not pay attention to student communication, which means that educational information cannot be provided on time.

The People's Republic of China's Ministry of Education proposed the goal of creating a web-based distant education platform in 1999 [4]. Domestic educational institutions and colleges have invested a significant amount of hardware and software resources in network education for this purpose. The fact that most domestic colleges have built a distance education system [5, 6] is a significant move. They offer online students with complete degree schools. Users will take classes online, complete required exams offline, and finish the course. Finally, the institution will award a learning certificate or certificate to the student. At the same time, some educational and training institutions charge for online learning [7], and by purchasing learning resources and paying for them indefinitely, teacher enlightenment has become a useful supplement to campus education, allowing more off-campus learners to obtain professional knowledge and training. On the contrary, these online learning systems are typically based on the replay of courseware and place a high value on knowledge acquisition, but they lack associated tasks. In most cases, learners merely need to create an online account to access on-demand learning resources and complete learning assignments [8, 9].

The study of curriculum learning in foreign countries is relatively early. After searching the keywords such as microlesson and collecting and reading a large number of relevant literatures, it is found that the meaning of the course learning represented by these keywords is more or less different. Even if the same term is the same, it will have different connotations with the different research fields or times [10]. Since the end of the 90s, network technology has been developed by leaps and bounds; people's thirst for knowledge is more and more urgent, and network distance education then arises at the historic moment. With its unique receiving mode and focus on individuality, network distance education, as a new type of education, has revolutionized the old way of education typified by "face to face" teaching and has sparked a global education revolution [8].

If education is to spread through the network, it must eventually use the network as a medium. In distance learning, the customer support system is an important carrier of network distance education. This is because it provides all of the learning support services required by distance education and offers great convenience to distance learners in the network, including learning resources such as learning content, learning processes, and learning methods. However, there are numerous issues to be resolved. Examples include the difficulty of transitioning from traditional education to modern education. In general, the lack of perfection in the construction of the learning customer support system severely restricts the use and development of the system. Learners can complete tasks based on their performance [11], which coincides with the remote support service's activity objectives.

Because of this, I should fully utilize performance learning theory and software design technology to lay a solid foundation for a learning platform system based on performance concepts, according to Jones [12], to change the current research situation that emphasizes technology. The research and development of having to learn system design method and application mode based on the concept of performance innovation, which provides more convenient, comprehensive, and efficient functions for distance learning, as well as continuously improve the distance learning support service system and support development, has significant theoretical and practical application value.

The following are the technological structure and functional elements of online learning systems in general, whether at home and abroad: ordinary online learning system, based on BSS structure, is characterized by strong system expansion [13]; there is no need to install any client, strong user expansion, and new learners can continue to join in; since the emergence of HTMLS, the client functions have gradually enriched, which is more suitable for online learning. Because the online education system usually realizes data communication with other systems, such as the courseware management system on campus, the layout and function design can be completed on the browser just like the traditional window system, and because the online learning system usually realizes data communication with other systems such as the courseware management system on campus, it needs to realize data sharing of multiple

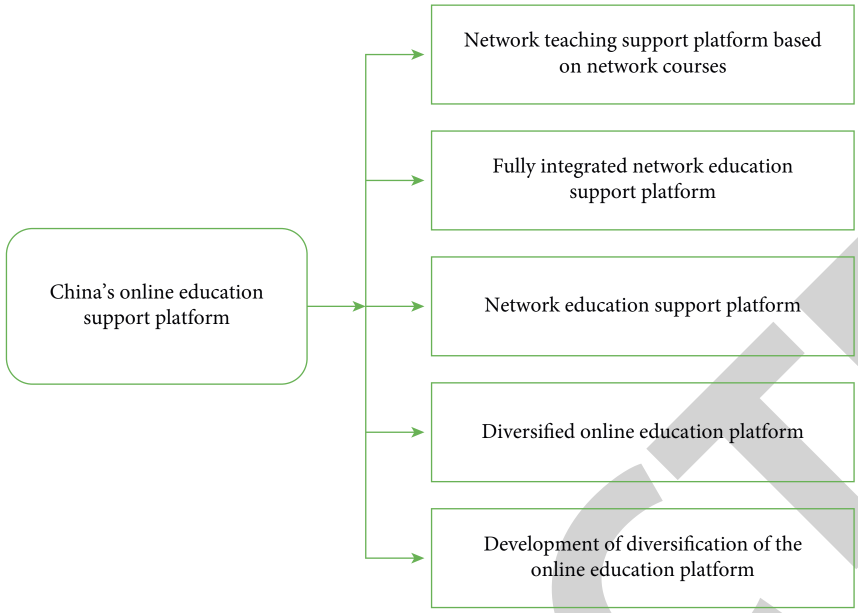

Figure 1: China's online education support platform.

systems through web services. In terms of functionality, most online learning systems rely on on-demand courseware and background data maintenance. Databases typically make use of huge commercial databases such as SQL Server and Oracle, although some also make use of the free MySQL database. A student-oriented front-end learning system is responsible for maintaining course materials resources, while system administrators or teachers are in charge of the system's overall function. Front-end code controls the playback of courseware resources, while server-side data is read. As a general rule, the background system handles the updating and maintenance of the learning resources and can import teaching materials in batches [14].

This article proposes an Android-based college music teaching system built on previous excellent efforts. This technology is portable, cheap, and simple to use, allowing for considerably greater flexibility in the distribution of musical course content. The program presented here is based on the JAVA EE framework, and it not only shows how to analyze musical teaching but it also covers a wide variety of subjects related to music teaching processing. In addition, AEPS is meant to create a genuine and creative learning environment through a simple Android user interface (UI), enabling students to experience augmented reality, encouraging students to participate in musical activities, and increase knowledge and understanding of information [3]. Besides, the music teaching system investigated in this paper is based on a thorough examination of the characteristics of traditional online learning systems. This investigation is also based on the application of current mobile Internet technology to complete the Android-based music teaching system as well as a system for learners and teachers to achieve a centralized learning and communication platform.

(i) First, I have briefly explained the related technology of music teaching system based on Android
(ii) Then, the model is divided into two kinds of music homework: one is the music homework of the independent learning type, and the other is the resource of the performance learning type
(iii) The proposed model performs queries, add, save, and delete music homework
(iv) After that, the throughput of the model has been checked by performing several experiments
(v) Finally, this method has the potential to improve student's musical awareness and comprehension

The following is a breakdown of the paper's structure. In Section 2, I offer a brief overview of relevant technologies for music teaching systems based on Android, and in Section 3, I discuss my suggested architecture for college music instruction. Section 4 then goes over the experimental works and their evaluations. Finally, Section 5 brings the paper to a close.

2. The Related Technology of Music Teaching System Based on Android

2.1. Java EE. JAVA EE is one of the current enterprise-level application system development frameworks because it is implemented in JAVA. In the current application system development, Java EE is the preferred platform, so in this research work, I use the JAVA EE framework. On the base of the work of [15, 16], the main features of the JAVA EE framework can be explained in Figure 2.

(i) *Strong Compatibility of Operating System.* Because Java is a cross-platform language, the Java EE application framework may support cross-platform redeployment, reducing enterprise investment costs. There are numerous enterprise information and data integration options available in today's enterprise application system. Each of them with its own set of benefits. Java EE applications may easily be distributed across operating platforms without affecting system settings or business logic.

(ii) *Rich Development Framework*. SSH framework, EJB, MVC model, and other development frameworks and modes are available in Java EE. Developers can swiftly change the application system to meet business demands using these frameworks. MVC mode, in particular, realizes the relative independence of data, business, and interface, as well as a fast and efficient data access interface. The design of business logic takes up more time and effort for system designers and developers.

(iii) *Good Load Balancing Regulation Mechanism*. When the application system has more than a particular number of concurrent users, a larger application server access, the system framework is automatically assigned which adjusts services' pressure and accomplishes the task scheduling system with the Java EE integration platform.

(iv) *High Application System Development Efficiency*. Without developers from the basis of creation, Java EE can flexibly use third-party released or produced programs, saving development time and improving development efficiency.

2.2. Model View Controller (MVC). MVC is a common development framework that uses the modular design concept to achieve the goal of application system maintainability by dividing the system into several layers. The structure diagram of MVC is illustrated in Figure 3. Its key characteristic is to organize the code of the application in a way that isolates the business logic from data and output presentation [17].

The following are the relevant descriptions of each part.

(i) *Struts' Presentation Layer*. This layer uses the MVC design pattern, allowing for the realization of data, logic, and view of phase separation. This layer is responsible for expressing that data is in its final form when it comes to the system's final data. This layer acts as a bridge for communication between the system and the users of the system:

$$\begin{aligned}
P\left(X_1|Z_{1;t}\right) &= kP\left(Z_t|X_t\right)P\left(X_1|Z_{1,r-1}\right),\\
P\left(X_1|Z_{1,t}\right) &= kP\left(Z_t|X_t\right)\int_{xr-1}^{N} P\left(Xt|Xr-1\right)P\left(Xr-1|Z1;r-1\right),\\
P\left(X_1|Z_{1t}\right) &\approx kP\left(Z_t|X_t\right)\sum_{i}^{N} wr-1P\left(Xt|Xt-1\right).
\end{aligned}\tag{1}$$

(ii) *Data Persistence Layer (Hibernate)*. This layer is a data persistence framework completed on the server side. Its function is to convert database tables into objects. Some operations on tables can be completed by calling corresponding methods of these objects, and it also realizes some optimized access operations of databases so that developers do not need to care about complex and changeable database operations. It improves the development efficiency of the application system:

$$q\left(X_t\right) = \sum_{i}^{N} wr-1P\left(Xt|Xt-1\right).\tag{2}$$

Then, priority can be expressed as

$$w_t = P\left(Z_t|X_t\right).\tag{3}$$

2.3. The Android Technology. The system's mobile terminal runs on the Android operating system because Android is a popular mobile operating system developed by Google, and its kernel is Linux. The majority of mobile terminal producers appreciate its openness and free features, and it has quickly become the operating system for smartphones, smart appliances, and other terminals in just a few years. It has now surpassed Android as the most popular smartphone operating system. Because of Android's open-source nature, major mobile phone manufacturers in the United States and elsewhere are working on Android secondary development and customization, which is tailored to the manufacturer's mobile phone operating system [18]. Android is divided into four layers when it comes to architecture: application service layer, basic framework layer, component and container layer, and operational kernel layer. In this section, I discuss these layers in much detail as below:

(i) *Basic Framework Layer (Application Layer).* This layer is also called application layer, which provides secondary development interfaces to finish the development of a specific function. Application system developers can complete the development of some functional features by using such positioning as mobile phone SMS records, rather than focusing on specific functional application interfaces and only by using interface calls.

(ii) *Component and Container Layer*. This is the second layer of the Android framework that includes core components and a component operating

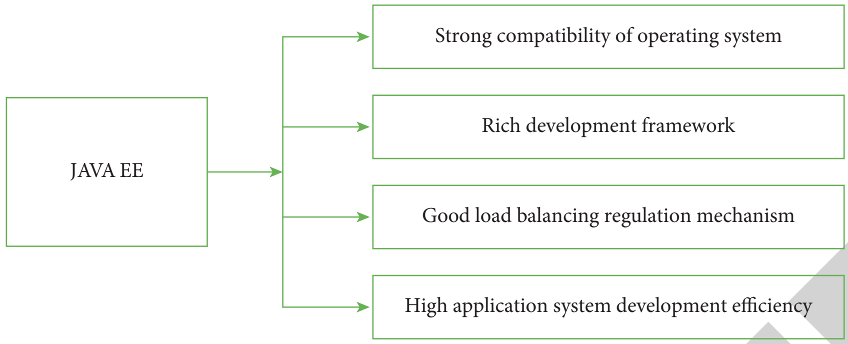

FIGURE 2: Features of the JAVA EE framework.

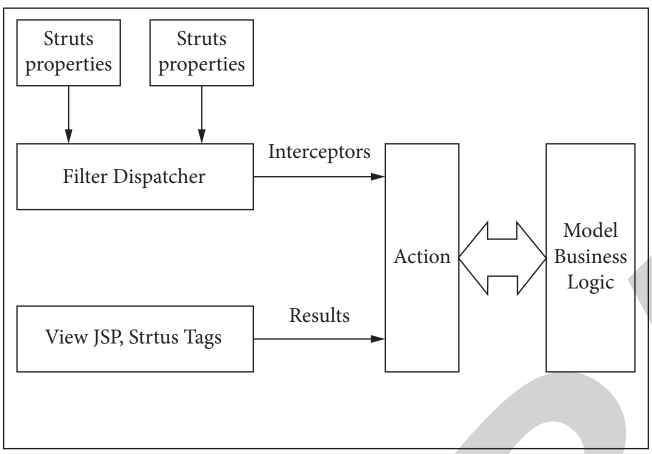

FIGURE 3: The structure diagram of MVC.

environment for Android's basic framework layer. The operational functions of Android are carried out by a set of components that are exposed and hidden via function calls such as a PC application system, which requires a specialized operating environment. These running environments, such as the.NET framework and the JAVA operating environment, constitute the cornerstone of the entire system's configuration and functioning.

(iii) *Operating Kernel Layer*. This is the third layer of Android framework, which executes related hardware operations through some of the core Linux integrated code, and it offers the underlying operation at the operating system level.

Using the above Android-related technologies, it is possible to complete the creation of necessary functions in the Android system as well as the Android data communication and operations of the database.

2.4. System Function Analysis

2.4.1. Basic Information Management Functional Model. According to demand analysis, end-users such as students, instructors, and administrators are typically beginning music courses that need comprehensive registration on the platform, which is done through a mobile operator. Students' registration information will be valid only when the examination has been approved, and they will be able to log in through the client. Figure 4 depicts the essential information about user management. Student management, teacher management, and manager management are the information management functions of my suggested model for users (such as students, teachers, and managers). Students may access multiple modules such as registration, check, change, delete, and load via the student management module which connects them to instructor management. The teacher administration is linked to the student administration as well as the manager administration. Teachers may access many modules such as registering, checking, modifying, deleting, and loading with the aid of teacher management. The managers, linked to the teacher management, may also have access to the same modules as teacher management and student management.

2.4.2. Student Music Homework Management Function Model. The music homework management feature of my suggested approach is discussed in this section. For a learning system, students must first gain information through music work; music work is the foundation of students' learning, and teachers educate; thus, the system must complete the music operation management job of maintenance. Because most online learning systems employ linked material such as video and audio, I used the same type of online learning system in this system. As a result, music homework takes the form of text descriptions and file attachments. Figure 5 shows how teachers may keep track of their music homework, post it, and remove it. Students can browse, query, and download music homework when the teacher has uploaded it to the system.

The usage of music homework is one of the markers of students' performance evaluation in my system. There are two types of music homework: autonomous learning music homework and performance learning resource music homework. Teachers submit music homework in the form of file attachments based on student needs. Music assignment, publisher, release date, and storage path are all examples of learning information.

2.4.3. Music Practice Management Function Model. Music practice is utilized to do musical practice on mobile telephones in pupils. The issues of practice are solved by mobile

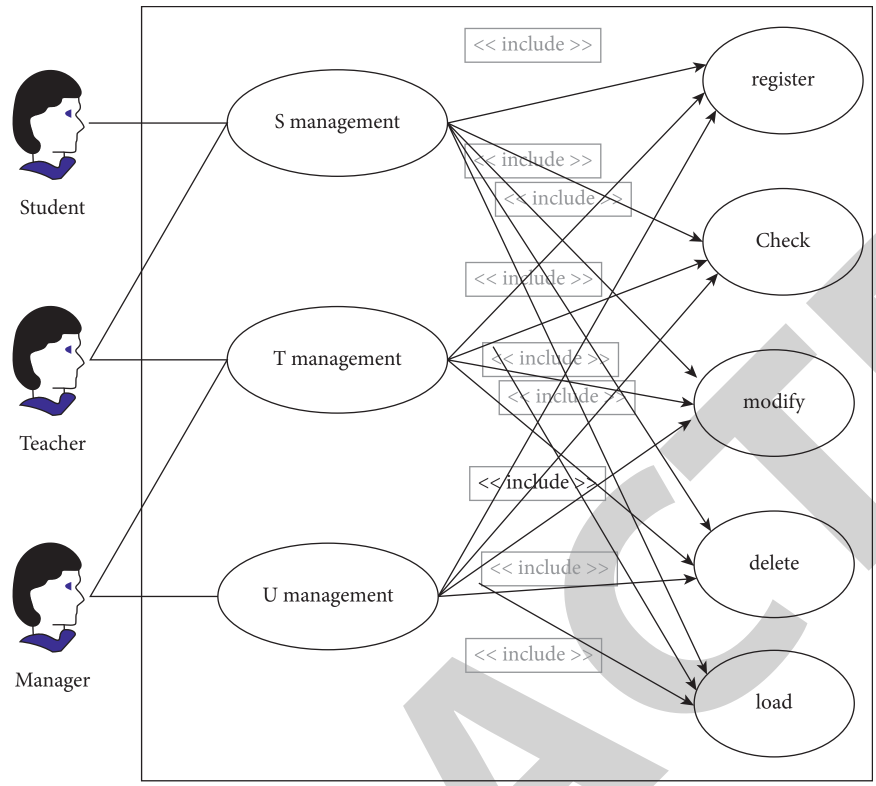

Figure 4: Basic information management use case diagram.

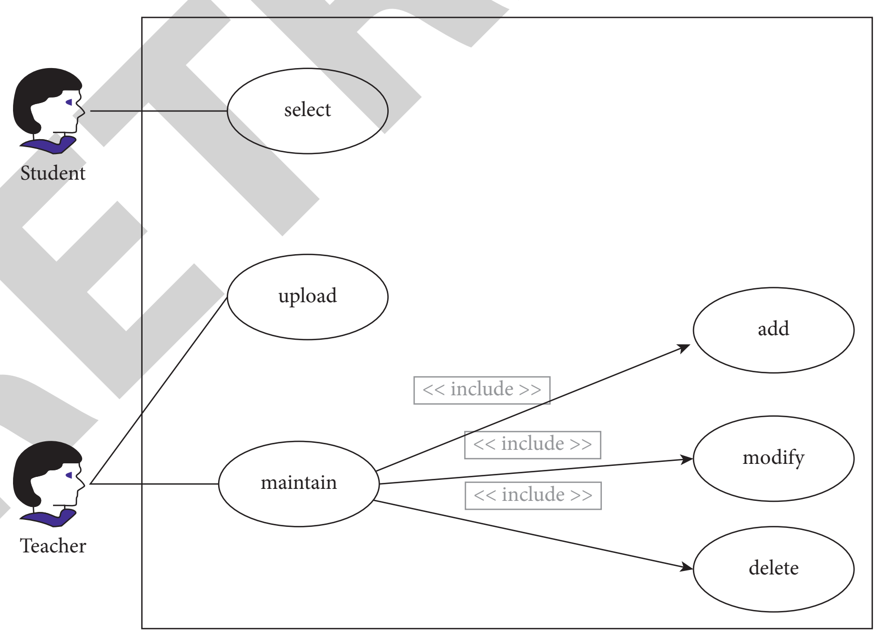

Figure 5: Music job management use case diagram.

telephones, including accompanying practices, testing practices, and works by prominent artists. Figure 6 shows the use case diagram. Besides pupils who complete accompanying exercises, tests, and works by great artists, teachers perform question banks and data maintenance works by renowned artists [19].

Classroom learning is a key component of the system since it needs students to broadcast on-demand online learning resources, keep learning logs, and post all types of learning questions online at any moment during the learning process. Teachers can use this platform to accomplish the

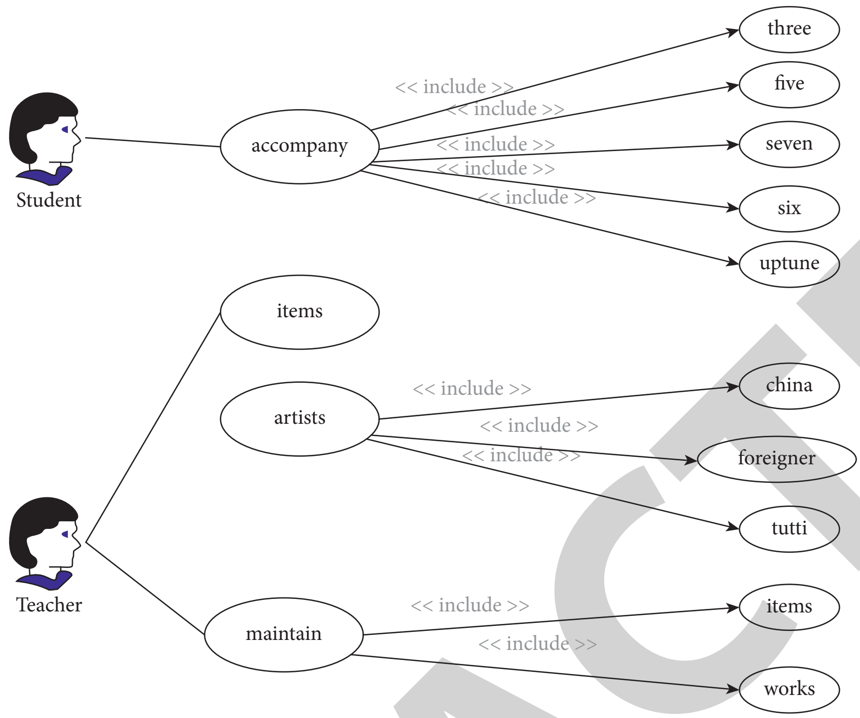

Figure 6: Music practice management use case diagram.

dynamic release of teaching information and notification for each student in the music teaching system.

2.5. Nonfunctional Requirements of the System. In this part, I outline my proposed system's nonfunctional needs. Nonfunctional requirements are the qualities that a software product should have in addition to functional criteria to fulfill the user's business needs. Nonfunctional needs of the music teaching system include system responsiveness, pressure resistance, security, and integrity. Figure 7 shows one example of this.

(i) *Performance Requirements.* As the system is designed to provide to multiple users, the number of participants may not be too high at the same time. This means that the system needs to meet 2000 user requirements during online work so that each student clicks learning resources online, and the system responds within 3 seconds. The system must also ensure that the student receives a maximum of 2 million people.

(ii) *Security Requirements.* System security needs are also an important indicator if the data are stolen maliciously; some individuals might have some influence on society; therefore, the safety requirements of the system are increased, and security requirements are not only met through the processing of user password encryption on the database platform but also by protecting unlawful intruders from a browser or a link to the client database by accessing the database. To make sure that as well as the relevant data and business associations can be viewed inside the system, other methods such as access to file information through file viewing mode can be seen in the ciphertext operation saving modes at all levels of the system. Furthermore, a security audit is necessary at all system levels. The system also offers an optimal system user permission and management method to ensure approved user management. This prevents unauthorized individuals from gaining access to the system as well as database security flaws and illegal injections.

(iii) *Normative Requirements for Development.* This article is considered from the point of view of the subsequent upgrade of the system because the business logic of the system is often changed by requirements, so the system development needs to be standardized to ensure the continuity of subsequent developers. The system design should conform to the software engineering development standard and the system architecture selection specification, and the database design should follow the paradigm standard.

(iv) *Operate Usability Requirements.* The system's friendly interface enables the operation efficiency and user comfort, and smooth operations to be improved, making it possible to lay down the system requirements page in line with business practice.

(v) *Stability Requirements.* A user-friendly interface can help improve efficiency by making operations more convenient and smooth for the user. As a result, the system requires a page layout that is in line with business operation habits, has clear and simple messages, and minimizes operator input while providing selective operation.

(vi) *Maintainability Requirement*. When a business needs change, developers may maintain and upgrade the system's business logic without altering the system's general structure, with little or no impact on the system's everyday use. The interface definition between the various levels of the system is necessary for addition to the layered and modular architecture of the system.

3. Design of Music Teaching System Based on Android

3.1. System Outline Design. The system architecture is separated into three components based on the system requirement analysis: the system data layer, the business logic layer, and the user interface layer. Figure 8 depicts the software structure of the system.

(i) *Data Layer*. The fundamental purpose of the system data is data storage. This layer generally carries out data storage, data queries, and data maintenance. In particular, the system database contains a music database of assignments, a student information database, and a learning database. This layer supports fundamental data and system business query interface. The fundamental purpose of data storage is to store basic data. This layer not only stores data but also provides a statistical interface and data inquiry. In this layer, all necessary system database activities are performed.

(ii) *Business Logic Layer*. This layer includes business rule definitions, business process settings, and user role rules. The business rules define the functional rules used to deal with music teaching systematically. User role rules are used to define student and teacher system role assignment and role authorization.

(iii) *User Interaction Layer*. This layer is used to implement the input and output operations of the system. This acts as a bridge between the user and system.

The physical structure of the system is described in terms of the connection of the system physical network, server deployment, and user terminal. Figure 9 is the physical structure diagram of the system.

3.2. Detailed System Design. User management is the management of users, such as students and teachers, according to the demand analysis so that the system function design comprises the class of users and the pupils. In addition to entering fundamental information, the data import operation must be completed using documents and the class of data import and class of file operation defined. The detailed class diagram for user management is shown in Figure 10.

Due to the complexity of the class, a typical operation is selected to describe the timing relationship. Figure 11 is the timing diagram of the review operation of student user registration information.

The architecture of the music homework management class is shown in Figure 12. This module creates the Resources class and the Resource file classes, which are used to perform queries, add, save, and delete music homework. Audio, video, and document materials, as well as other relevant resources, are included in music homework. Because different types of resource files require different ways to open the page, the system uses the ShowFile class to complete the file display; the UploadFile class is used to upload the resource file.

Music practice is utilized to do musical practice on mobile telephones in pupils. The issues of practice are solved by mobile telephones, including accompanying practices, testing practices, and works by prominent artists. I have thus developed the fundamental operating class of the students, the students' practice class, the score management class, and the score importing class. Figure 13 shows the complete diagram of student information.

With the analysis of the system and system design, the system's function to achieve a detailed understanding of the system is to support a system through a database, so the system database design needs to be complete in this section, using the system database conceptual model and the physical design of the system database. As I know, there are three elements in the design of databases. In this portion, the conceptual model diagram of the database describes the system's conceptual design and logical design, while the core table structure describes the physical structure of the database.

4. The Realization and Test of Music Teaching System Based on Android

There are two kinds of music homework: one is the music homework of the independent learning type, and the other is the resource of the performance learning type, in which the independent learning type does not count and is uploaded and maintained by system administrators and teachers, while the performance type is included in the assessment score and can only be uploaded and maintained by teachers [20]. According to the learning module, the teacher uploads the music homework, which exists in the form of a file attachment. The learning information includes the music homework, publisher, release time, and storage path. The system distinguishes between two types of music homework: autonomous studying music homework and performance learning materials. The autonomous learning type is not included in the assessment score and must be uploaded and maintained by teachers, but the performance type is included in the assessment score and can only be posted and maintained by instructors. According to the learning module, the teacher submits the music assignment, which is in the form of a file attachment. The music assignment, publisher, release date, storage path, and other learning information are all included in the learning information. Learners can locate their desired courses via course classification or by searching directly for resources. The user may utilize the

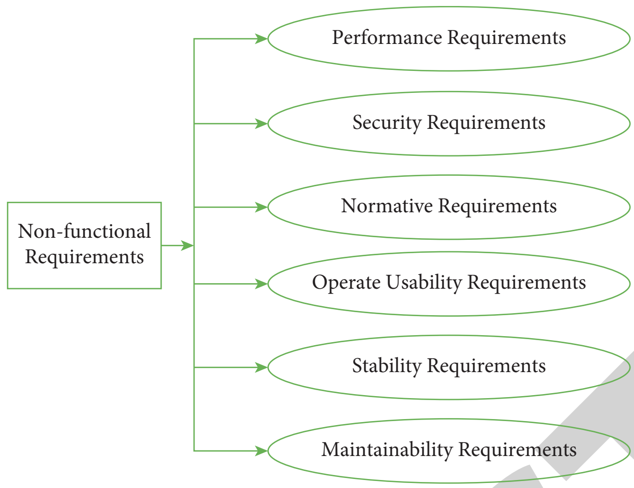

FIGURE 7: Nonfunctional requirements.

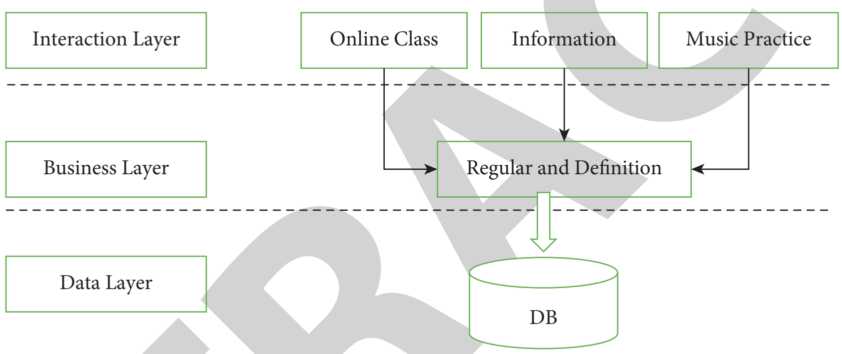

FIGURE 8: System and software architecture.

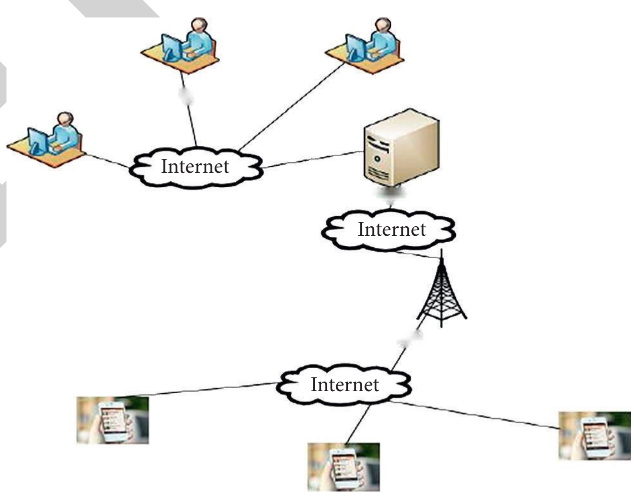

FIGURE 9: The physical structure diagram of the system.

management tool to modify the course design and the learning tool to complete the learning job. Figure 14 shows the system home page.

This part implements the following functions: a system database uses an SQL server, a database interface is created through a unique database access interface, and a class is used to link the database. The execution object of the data commands, data set object, and associated methods for database operation, such as data query and database update, are specified in this class.

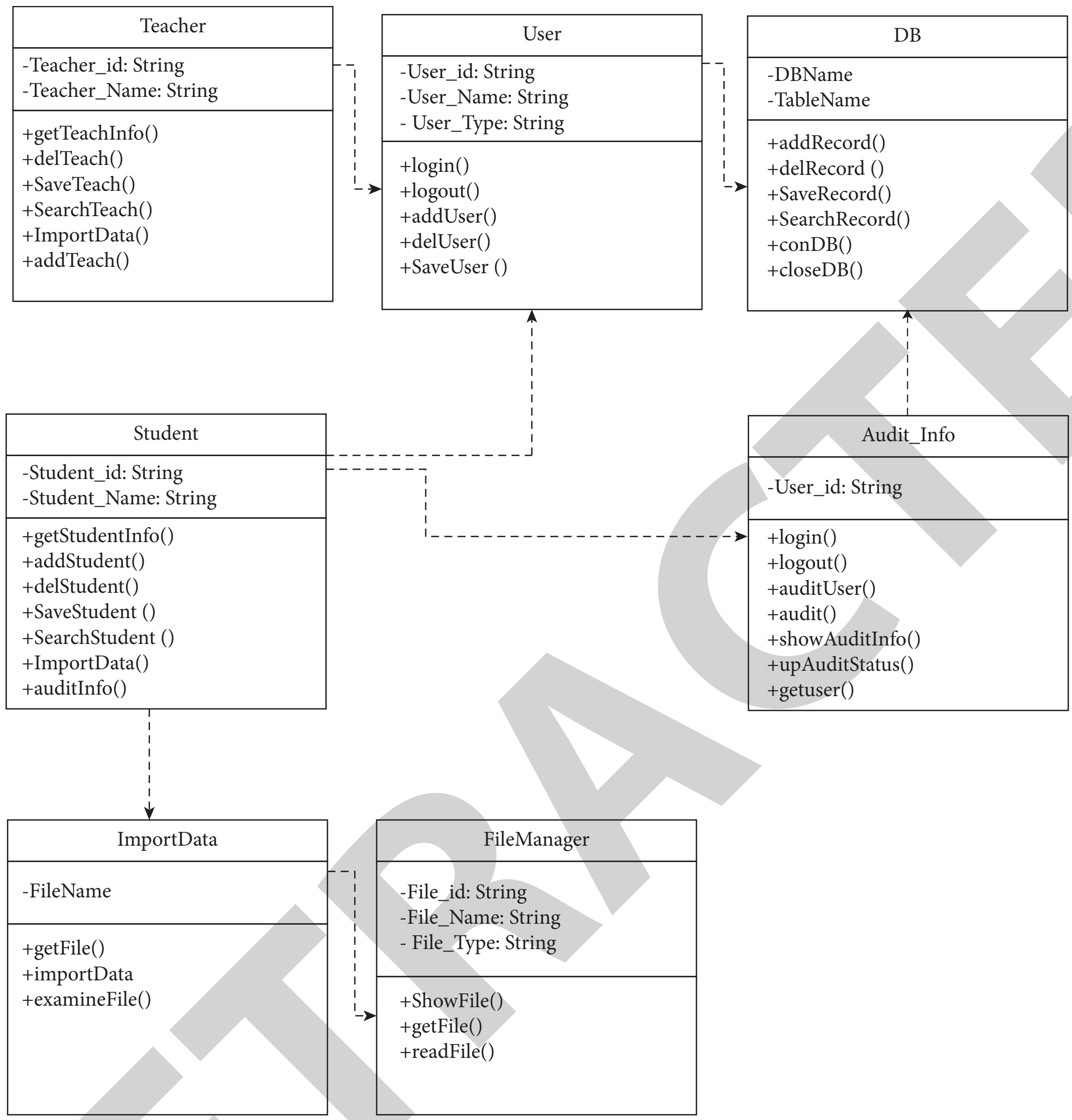

Figure 10: User management detail class diagram.

The masterwork list is acquired in the JSON form, and a first picture of the masterworks on the customer's side shows the masterworks. You need to click to reach the detailed view if you are looking for detailed masterworks. These thumbnails are generated using the image via the server code, and no need for the client to download the entire image. Thumbnail processing is through the third party class to complete, with no programming implementation. When these thumbnails are sent to the mobile phone terminal, the mobile phone terminal takes the picture form as the folder (directory) of the works of famous artists. In the topic of basic information and masterworks maintenance operation, the operation is based on the database operation to achieve, so in the server through a Java class to complete the corresponding database operation and through the call to different methods to complete the data operation.

The online classroom is that learners can arrange to log in to the system for learning detection at any time after setting relevant goals and performance. You can utilize the learning tools in this module to capture notes, impressions,

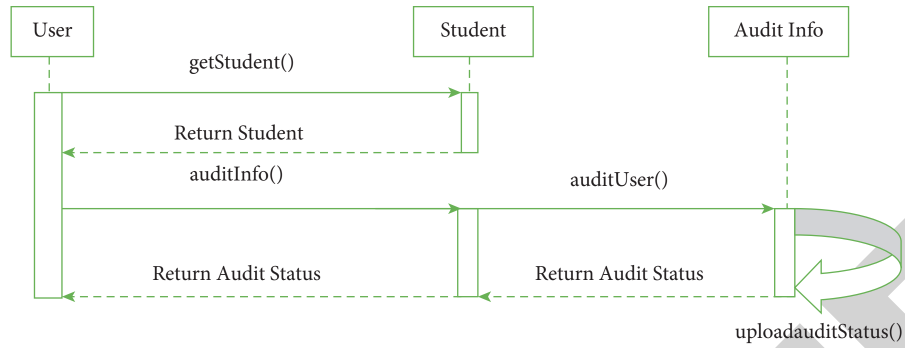

FIGURE 11: Time sequence diagram of the student information review.

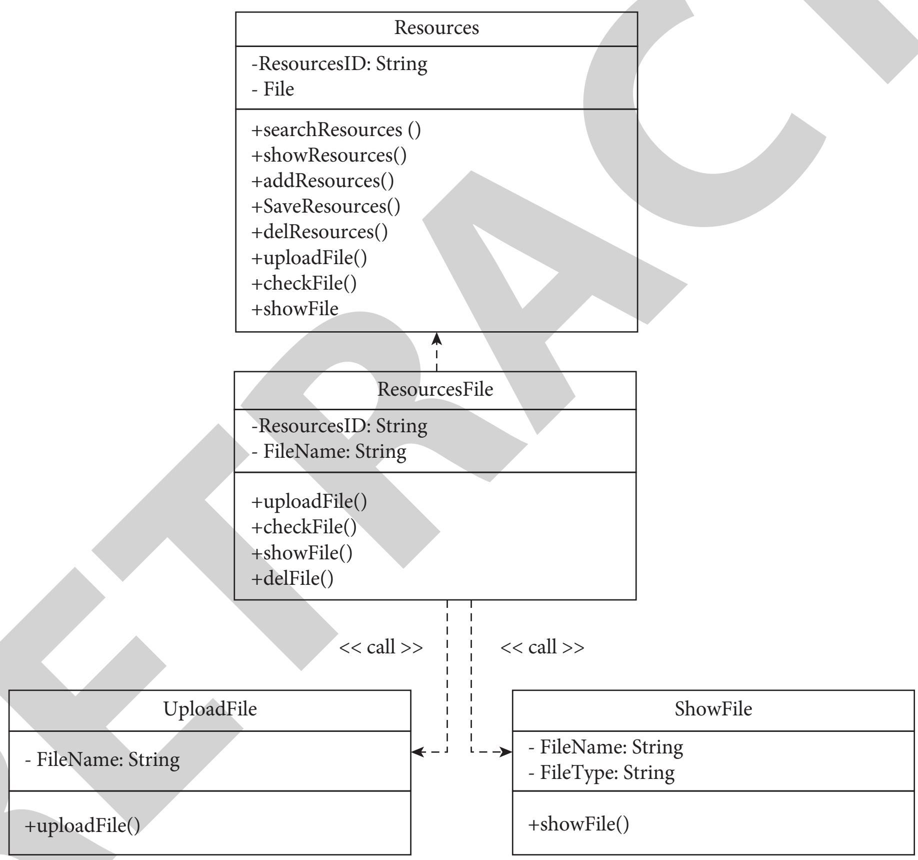

FIGURE 12: Music homework management class design.

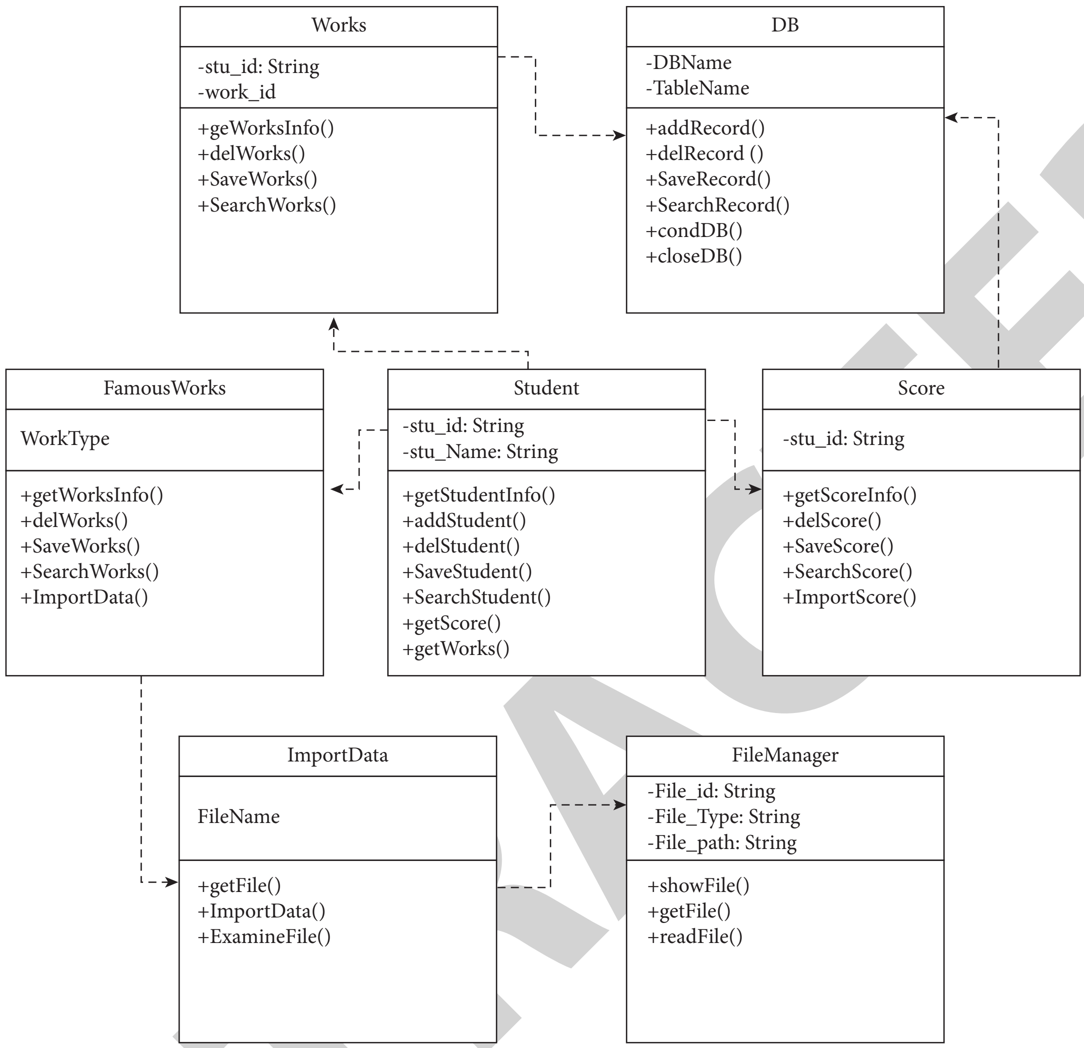

Figure 13: Detailed class diagram for music practice.

and issues throughout the online session for future reference. Online class includes classroom study, study log, study reflection, online questioning, and resource browsing:

(i) Classroom learning is used to select and play learning resources online, and the system will automatically record the starting time of learning

(ii) Learning log is used by the system to record learners' selection of various resources in the learning process and to play the daily catalog

(iii) Learning reflection is used to record the summary and reflection of related problems of learners in the learning process

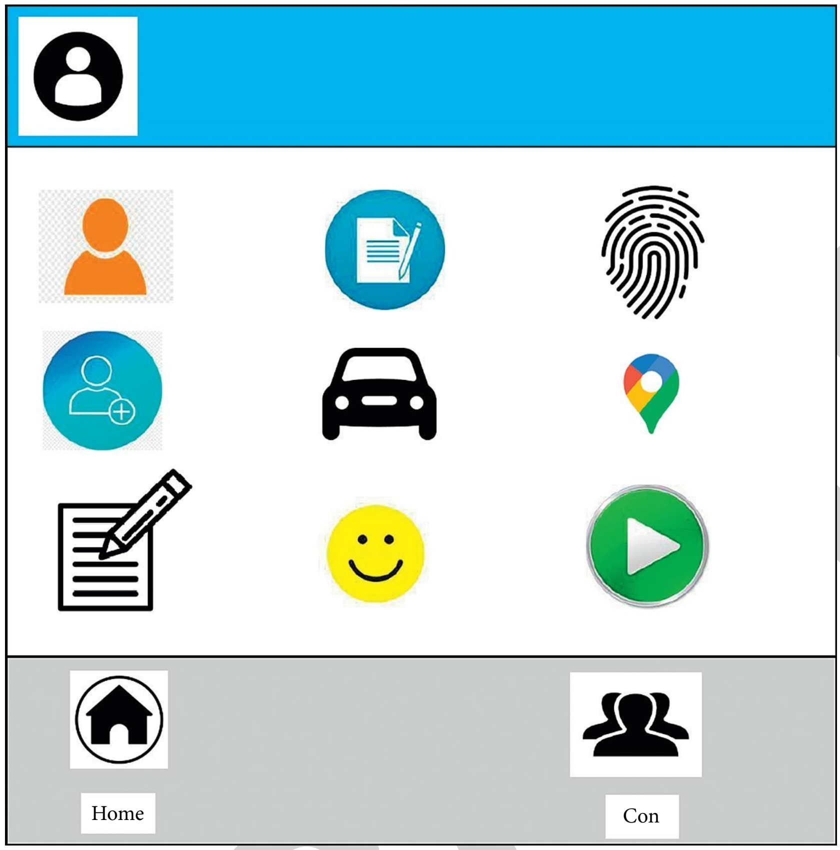

Figure 14: Homepage of the system.

(iv) Online questioning means that learners put forward questions related to learning online, and the answers are answered by teachers

(v) Resource browsing is to query learning resources by entering keywords

Functional testing entails executing test cases and executing tests by selecting a function from a menu and inputting appropriate data and circumstances. It is possible to test the data maintenance feature to check if it can be saved normally by entering data.

Figure 15 depicts the system throughput test results. Under the condition of 200 concurrent users, the system's average throughput is 18213.363 bytes/second, the maximum throughput is 20073.653 bytes/second, and the minimum throughput is 6726 bytes/second.

According to the system response time test results shown in Figure 16, when 200 concurrent users access the system, the average response time is 0.358 seconds. In general, when 200 concurrent users access the system, 10 seconds can meet the expected design goal; however, when some client hardware configurations are taken into account, within 1 second can meet

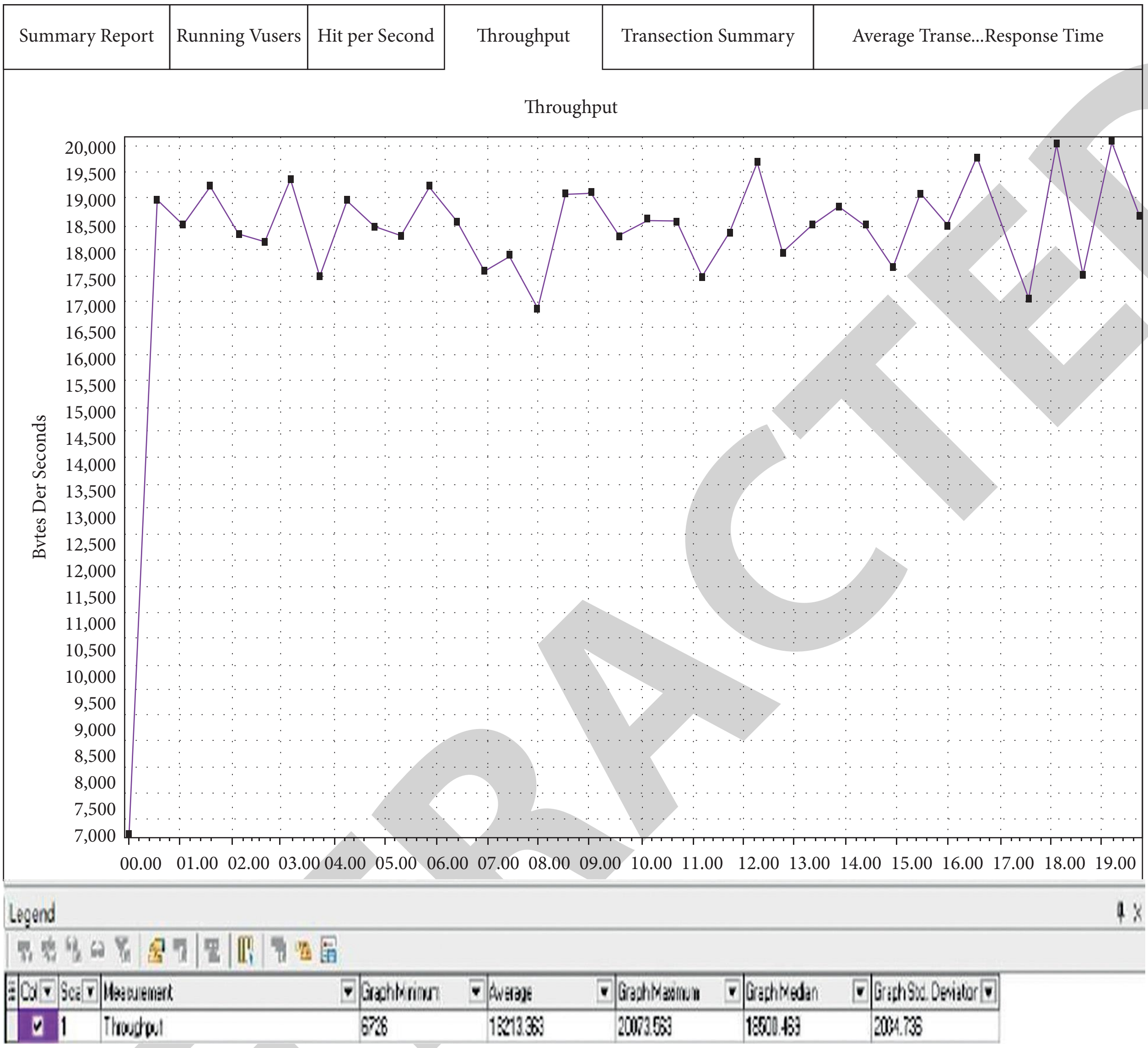

Figure 15: System throughput test results.

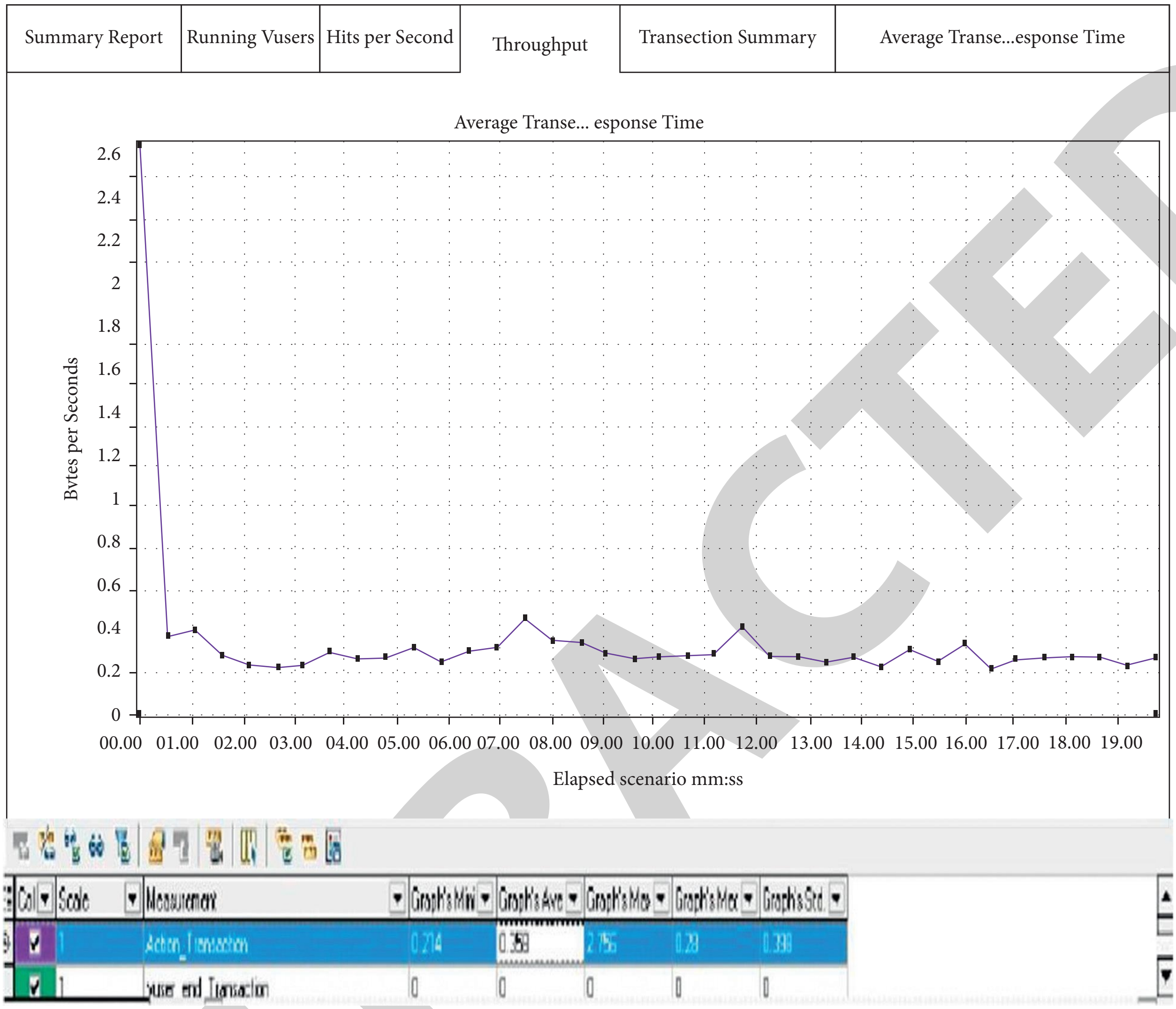

Figure 16: System response time test results.

the performance requirements of the actual operation. In conclusion, the system function and performance tests have been conducted by the test strategy. The test results demonstrate that the system satisfies the system's criteria.

5. Conclusion

The music education system is distinct from that of other subjects. The requirement to recognize sounds through notes is a significant professional aspect of music instruction. This article offers a music education system based on the Android platform to get a better music teaching impact. The system makes extensive use of multimedia technologies on the Android platform, and the teaching system has a basic interface design that reflects the peculiarities of the music profession. Learners may make full use of their spare time to complete learning and exercises by taking use of the ease and speed of today's mobile Internet. This improves their learning efficiency. At the same time, this paper's study is based on server data release and mobile front-end functional views to create a framework for music education system design. The first two layers offer data support for the system's front end, while the entire structure provides a solution for the system's data processing, service, and function presentation. The system function and performance tests have been conducted by the test strategy. The test results demonstrate that the system satisfies the system's criteria.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

Acknowledgments

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Research Article

Research Onion for Smart IoT-Enabled Mobile Applications

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Determining the appropriate approaches and procedures to gain sufficient results is a vital issue that is faced by the majority of researchers. Each type of research can have several methodologies that can be applied. Yet, one approach might lead to concluding more effective outcomes. Thus, designing the research and applying appropriate methods and techniques are the key aim of this experiment. Combining the research onion framework with an advanced Internet of Things- (IoT-) enabled mobile app solution within the real world is the foundation of this research. The framework has six main layers, starting with philosophy and ending with techniques and procedures. This research begins by providing a brief introduction in regard to the selected framework. Then, it provides a comprehensive explanation regarding each of the framework layers and justifying the chosen element within each layer combining with the advanced IoT-enabled mobile app for this research study. Later, it highlights the challenges that can be faced while using such a framework.

1. Introduction

The selection process for a research methodology which is a related framework without a doubt is one of the hardest and most confusing phases that face the majority of researchers. This is due to the fact that each type of a research requires a specific kind of approaches and procedures which are used to collect data and then analyze them to present a valuable finding. A common question that was asked by many researchers is that "How do we determine the right methodology, which is related framework, techniques, and procedures for our research?." Answering such a question is not easy because of many factors. These factors include the convictions and interests of a researcher, the aim and objectives of a study, and the type of data that needs to be collected.

There are numerous research methodologies and frameworks, and each has its own advantages and disadvantages. One of the most common and comprehensive research frameworks is "The research onion" [1]. The research onion and nested method are major research frameworks and are used widely in research [2]. Figure 1 shows the research onion framework.

Each layer of the framework covers one specific aspect of the study, demonstrating the variety of paradigms, strategies, and choices that researchers use throughout their investigations. It shows all of the significant issues that need to be taken into consideration during any research project. The model has six layers: the researcher's philosophical position, the approach, research strategies, choices, research timelines, and the data collection techniques employed by the researcher.

This framework has a powerful multidisciplinary application, which makes it appropriate for research. This framework has been used successfully in previous studies related to mobile apps and technology [3–6]. A work in [4] used this framework to figure out what features of mobile apps and their releases influence apps' popularity. Another work in [6] used the research onion to analyze m-Commerce security requirements and explore how system security performance can be improved. Moreover, the study in [3] used this framework to demonstrate how online advertising impacts consumer behavior. In addition to this, the study in [5] used the model to examine how the use of technological tools by project managers can affect the chances of a project's success. This framework has also been used in various

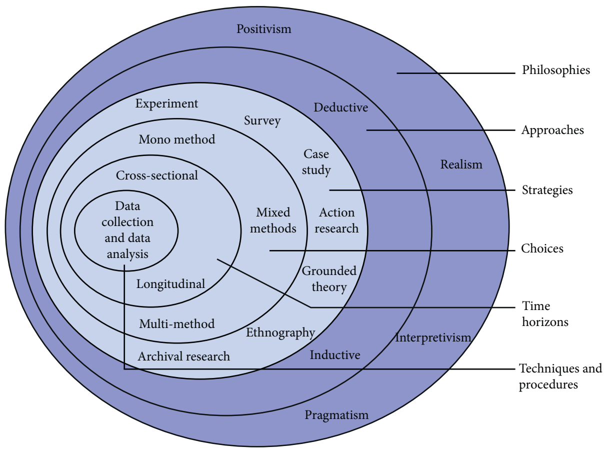

Figure 1: Research onion.

research projects, such as [7], which utilized it in a Ph.D. thesis at the Royal Melbourne Institute of Technology (RMIT). A work in [8] used Saunder's model to form a research strategy for developing a framework called "kaizen costing" that is both suitable and helpful for construction firms in Lagos, Nigeria. Their research follows a systematic approach and builds upon a research philosophy that uses an approach that is based upon a variety of research techniques and strategies.

Based on the previously mentioned literature, it is clear that the research onion framework was used in several studies related to mobile apps. Moreover, this research aims to further explain how to effectively and efficiently integrate the research onion framework with a smart IoT-enabled mobile app. This is done by conducting an inclusive literature review regarding the framework. Furthermore, explaining in depth each layer by determining and justifying the selection of the elements within the framework layers is another major contribution of this work.

The next heading provides a comprehensive literature review about the research onion framework. It explains and justifies the selection of each component from all the framework layers in depth. Following this, the expected challenges which might be faced while implementing the research onion framework are indicated. Finally, the paper ends with a brief summary and highlights areas of interest for future work.

2. Related Work

According to [1], research philosophy is an overarching term that is related to the character of knowledge and its development in the research context. The research philosophy shows how the researcher views the topic and contains important assumptions upon which the researcher will base their work. The research philosophy is the basis for the strategy that will be adopted by the research: it determines the methodology that will be used to answer research questions, the data collection procedures and techniques, and the analysis of the findings as well as the presentation of those results derived from data analysis.

There are various research philosophies that can be adopted, such as realism, interpretivism, pragmatism, and positivism. According to positivists, the reality is stable and constant, and an objective viewpoint can help describe and observe it; for example, there is no need for inferring with the phenomena that are under study [9]. They believe that there should be repeatable observations or that the phenomena should be isolated. To find the relationships between different variables and identify regularities, positivists may vary or manipulate a single independent variable. Previously explained and observed realities and their interrelationships can be used to make predictions.

Interpretivists believe that reality can be understood through subjective interpretation and intervening in reality [10]. Their philosophy involves the study of phenomena in their natural environments. Furthermore, they consider that there could be more than one interpretation of reality. In contrast, realists are of the opinion that certain objects can exist independently of their being observed [11]. Scientific realism states that a scientific theory must refer to real objects in the universe. Reality is anything in the cosmos, such as structures and forces, which cause phenomena that are perceived with our senses [12].

In pragmatism, philosophy means an idea or a concept that has practical consequences. A work in [13] argues that we can reach something that is tangible and practical for every real distinction to make our ideas clear. In science, the pragmatic approach is about using the methods that are best suited to the problem the research is addressing and therefore avoiding the debate of which approach is the best. This is the reason that pragmatic researchers are at liberty to make use of any techniques, methods, or processes that are involved with qualitative or quantitative research. They understand that every procedure has its strengths and limitations and that different methods sometimes pair well together [14].

2.1. Pragmatism. The author in [15] believes that pragmatism has the central idea that if it is worked, it can be said and then it is true. Even in this century, the meaning of pragmatism as to do what works well is supported by many researchers [16]. From the point of view of academia, pragmatism as a research philosophy has the definition which debates that the correct and the right idea is the one that has been successfully proved in a practical way [17]. In addition to this, pragmatism as a research philosophy supports the building of a conceptual foundation on a real-life practice and believes that there are multiple correct answers for any research study [1].

One key advantage of this philosophy is that it allows for a combination of research approaches, methods, and strategies so that research questions can be answered more appropriately for better applicability. However, this advantage has been criticized by various authors as a failure of this philosophy to adhere to theory and as a sloppy way of thinking [17]. However, what these critics forget is that this philosophy was dominant in the latter half of the 19th century, a time during which the United States (US) emerged as a significant power due to unprecedented political, knowledge, and economic growth. If there were serious flaws in pragmatism, then it would not have allowed for that rise and growth to take place. In addition to this, multiple realities exist in real life; thus, a philosophy like pragmatism, which has the ability to contain diverse views, is needed.

I believe pragmatism is an appropriate philosophy for this research for the following reasons:

(i) The nature of this research is practical, as the usability of several Internet of Things- (IoT-) enabled apps has a conceptual foundation that is greatly linked to the user experience (UX) or real-life practice. Pragmatism is different from other philosophies because it is not restricted to explanations and understanding, as is the case in positivism and interpretivism, respectively. Pragmatism has the advantage that other knowledge forms, such as normative, prescriptive, and prospective, are essential to it [18]. This is why pragmatic philosophy is adopted for explaining, understanding, and suggesting usability characteristics in IoT-enabled apps to enhance the UX. I will try to incorporate these diverse knowledge forms into this research within a pragmatist epistemology as constructive knowledge. In turn, this will provide both descriptive and explanatory knowledge about usability. The empirical focus of this study is actions and changes, and this is inherent in pragmatic philosophy [19]. This research is an inquiry into how IoT-enabled apps can be improved.

(ii) The data required to conduct this study not only exists in different forms but is also spread across different sources. The pragmatic approach advocates a variety of data collection tools. This research relies mainly on qualitative data but there will be some quantitative data used, and a pragmatist approach allows for this combination. Therefore, to reach accurate conclusions from this investigation, I will need to collect and examine both types of data.

(iii) Pragmatism holds to the basic principle that there could be more than one correct interpretation. Usability studies of IoT-enabled mobile apps can have more than one interpretation; for example, a certain feature enhances the UX and this could be because that feature improves the performance and/or even the satisfaction of the user. Given that there can be more than one correct interpretation of the feature, the use of both objective observation and subjective meaning might lead to creating knowledge that is accepted. This study needs the use of not only objective observation but also subjective meaning in order to build inferences from the data.

(iv) Pragmatism argues that the role of the researcher is to engage in change. In pragmatism, interpretation is instrumental and closely linked with any change of existence [20].

Because of the reasons mentioned above, I believe pragmatism as a research philosophy is appropriate in order to build a solid philosophical foundation within this study.

3. Research Approach

There is a strong link between research and theory. The research approach is the movement trend between research and theories. Inductive and deductive approaches are the major research approaches that exist [1]. In deductive reasoning, the researcher moves from more general to more specific [21]. The deductive approach starts with a compelling theory and then the implications of that theory are tested with the data. The deductive approach is therefore associated with the scientific investigation [22] (Figure 2).

The deductive approach is considered a top-down approach as that the conclusion must arise logically from the premise, as shown in Figure 3.

Inductive reasoning moves in the opposite way, starting with specific observations and moving toward broader theories and generalizations. When using an inductive approach, the researcher collects the data and then figures out the data patterns and tries to develop a theory to explain those patterns. An inductive approach begins with a set of observations and then moves toward a general set of propositions. It is sometimes described as a bottom-up approach. This is shown in Figures 4 and 5.

Table 1 summarizes the differences between the two approaches as described in the work of [1].

These two approaches can be used independently but can also coexist in some research work [1]. In this study, I will combine the two approaches. The advantage of combining both approaches is that it will allow us to understand all the usability attributes, factors, users' social and cultural norms, motivational features, and design elements that can impact the usability of IoT-enabled mobile apps. It will also help us to find the link between an app's success and the attributes or characteristics causing such hit. Another advantage of using these approaches together is that it will enable us to utilize and take advantage of not only qualitative data but also quantitative data.

A combination of the two approaches also has the advantage in that it provides the flexibility required for both the exploratory and explanatory parts of the research. This study has an exploratory beginning, where I will evaluate various IoT-enabled apps to see which usability attributes and factors, social and cultural norms, motivational features, and design elements make these apps successful. Therefore, I will be exploring something that needs a flexible approach. Once I know the aspects that are required for a successful IoT-enabled app, I will adopt a more structured approach and I will use an inductive–deductive combined approach in this study. Many researchers have used this combined approach extensively. A work in [23] used inductive and deductive thematic analysis to reduce the data into various themes so that they could explore the benefits of health apps for health monitoring and suggest improvements in health apps. A study was conducted in [24] with the aim of coming up with

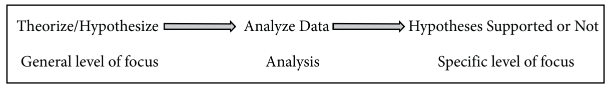

FIGURE 2: Deductive approach.

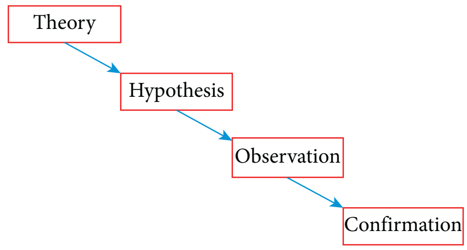

FIGURE 3: A model of a top-down deductive approach.

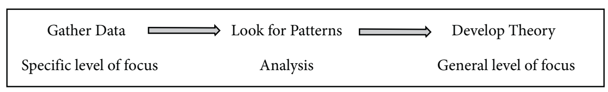

FIGURE 4: Inductive approach.

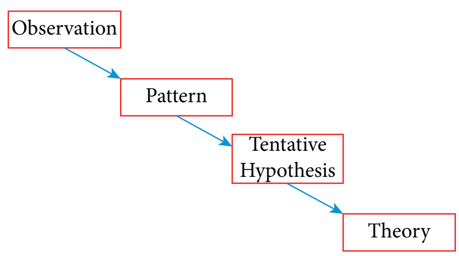

FIGURE 5: A model of a bottom-up inductive approach.

TABLE 1: Differences between the inductive and deductive approaches.

Inductive approach	Deductive approach
Based on understanding the meanings humans attach to events.	It is based on scientific principles.
The researcher should have a detailed and complete understanding and knowledge of the research context.	The approach moves from theory to research. The researcher explains and finds casual relationships between variables.
It involves collecting qualitative data.	It involves collecting quantitative data.
It adopts a flexible structure that allows for changes or variations in research emphasis along with the progress of the research.	The researcher introduces and applies controls to ensure and protect the validity of the data.
The researcher has an evident realization that they are part of the process.	To ensure clarity of data, the concepts are operationalized.
The researcher is less concerned about generalization.	It is a very structured approach. The researcher has a lot of independence. There is a need to have a large enough sample size to make conclusions.

a multimethod approach and a feasibility test for data-collecting and analyzing data about patients' usability experience when using an m-Health system that was meant for the self-management of type 2 diabetes. The authors used usability problem taxonomy (UPT) and framework analysis (FA) to code, design, and analyze the findings. After classification, the scholars assigned a rating based upon usability severity. They used the inductive approach for coding usability descriptions and problems and then used deductive coding using UPT classification. A study in [25] used both deductive and inductive reasoning in his research work to explore the relationship between usability and persuasion.

In this research, an inductive approach is used which is based on the observation that some IoT-enabled apps are very popular and investigates how these apps can benefit individuals. This observation allows us to find and compare some of the most successful apps in order to determine the reason for their success. This leads us to find out the usability attributes, motivational features, and design elements that are most sought after in IoT-enabled apps, thus helping us to build usability guidelines for IoT-enabled apps. I then develop an IoT-enabled app and use the deductive approach to test its usability level.

4. Research Strategy

There are several kinds of research methods or strategies that are affected by the research philosophy and types of inquiries for which an investigation aims to provide the answer. Before determining the research strategy, there are several aspects that should be considered, for example, the type of data, the available tools and equipment, and the kind of resources required [26]. In the following subsection, the selected research strategy is presented.

4.1. Experimental as a Research Strategy. I use experimentation as the main research strategy in this research. I will discuss the strengths and weaknesses of this approach in the following subsections. I will also present the justification for choosing experimentation as the most appropriate strategy for this research.

Experimental research has a long tradition in medicine, technology, education, psychology, and various other fields [27]. The purpose of experimental research design is to help the researcher to establish a cause-effect relationship with a lot of credibilities. Experiments have a particular nature; they are conducted in a systematic way and under controlled conditions. In an experiment, an artificial situation is formed and events that go together or have something in common are pulled apart [28]. The experimental method is a scientific and systematic approach in which the researcher uses controlled and manipulated testing to gain an understanding of the causal processes. A widely used definition for experimental research strategy is when scientists actively influence something to observe the consequences [29]. This is the best strategy to use when

(i) The researcher is trying to find out whether the cause precedes the effect or is investigating the effect of changing conditions on objects/subjects

(ii) A causal relationship exists between variables as one variable impacts others

(iii) The magnitude of the correlation between two variables is great

(iv) An accumulative method of inductive inference is required

(v) It is necessary to explore the unknown

Experimental research strategy can be categorized into the following types of experiments [27]:

(i) Laboratory experiments: these are carried out in settings that are specially created and the experimenter has the ability to control a variety of extraneous variables

(ii) Natural experiments: these are referred to as quasi-experiments. These studies are conducted when a natural event or social policy creates situations suitable for the experiment. The investigator has no control over independent variables. The subjects are neither matched in groups nor randomly assigned

(iii) Field experiments: in these experiments, independent variables are manipulated by the researcher in a field environment

Experimentation as a research methodology has been used in a lot of work related to usability. The experimental study of usability started in the 1980s. One of the most influential works to be published during that period was in [30], who examined a computerized banking system using an experimental design. The study presented a summary of variables that affect the usability of the system. The paper also examined the methodological implications of using an experiment as a research framework and advocated the use of field experiments to better understand the concept of usability. A work in [31] did an experimental study to find out if a user demonstrates greater efficiency and success in tasks when given product or task-oriented instructions. The research findings showed that clear and improved instructions improve usability. Similar research was conducted in [32], who discovered that structured or multilevelled manuals help users understand and teach accurate mental models of a computer system better than detailed or global manuals. Research in [33] showed how mobile Internet usability can be improved; in this case, the methodology adopted was experimental design. Research in [34] tested mobile app usability using mobile eye-tracking glasses. Finally, [35] examined the usability of mobile apps running on different platforms with the aim of improving understanding of the influence of devices on the usability of mobile apps.

In this research, I will use usability testing in a laboratory setting as this is the most appropriate strategy. Usability testing is an immensely popular tool to evaluate mobile apps' usability. I will use the "think aloud" protocol, which is based on the work of [36, 37]. Traditionally, usability tests are conducted in laboratories. A laboratory is a peaceful environment where the user can easily concentrate on the tasks provided to them. The details of this will be outlined in the next section.

4.2. Strengths and Weaknesses of Experimentation as a Research Strategy. There are various advantages of using experimentation as a research strategy. If properly conducted, it is considered one of the most accurate and efficient ways to compare apps and their usability and reach conclusions [38]. First of all, in experimental research, the researcher has control over many of the independent variables. This control of independent variables helps the researcher to remove those that are unwanted and extraneous. This type of experimental design gives an advantage to the experimenters to find a cause-and-effect relationship through manipulating the independent variables [39]. This research design has also the benefit of being able to be used in many different ways and has been used in a wide range of research from pharmaceutics to education. It may be basic, but it is an efficient research strategy [38]. Using experimentation as a research strategy has another advantage in that it can be tailored to suit each situation. Experiments usually start with randomly assigning conditions to produce equivalent groups where one group is subject to conditions different from other groups. Isolation and the manipulation of independent variables to find causal effects are therefore other necessary components of experiments.

While the experimental strategy might produce results that are less realistic or natural than other research strategies, it is still useful in identifying a causal relationship, which might be difficult to do while using other research methods. It is primarily chosen by researchers if they want to identify or establish a causal relationship between variables [40].

However, as a research strategy, experimentation has various disadvantages. Experimental research is subject to various errors such as human, systematic, or random errors. These can at times affect the credibility or validity of the results from the experiment [39]. Another major disadvantage of adopting this research strategy is that it involves at times controlling variables that are irrelevant, which can create situations that are unrealistic or artificial [38]. Many confusing variables in a usability experiment come from the fact that it is related to UX. For example, imagine someone is invited to be part of a usability experiment even if they do not know anything about usability. They would want to know what the experimenter is trying to find through this experiment. There are expectations by the experimenters from the results that are to be achieved from the experiment [41].

5. Research Choice

This research can be described in two ways: quantitative and qualitative. The main differences that separate the two types are the procedures and techniques, which focus on either verbal (words) or numerical data. Quantitative studies have a numerical focus and utilize quantifiable techniques of collecting data (questionnaires, for example) or numerical procedures of data collection (including graphs or statistics). Qualitative studies are focused on words, and they adopt methods for collecting data that are nonquantifiable (such as videos and interviews) and the results generated by data analysis procedures (like content analysis) are nonnumerical.

In their research onion framework, [1] describes the choice between the qualitative and quantitative types or a combination of both in research procedures and techniques as the research choice. The possibilities available in the framework outlined in [1] are shown in Figure 6 and described in Table 2.

In this usability research, I am looking at both technical aspects and some cultural and social norms; therefore, purely qualitative or quantitative procedures may not reveal some important aspects of real-life situations. According to [42], after each usability test session, data needs to be compiled, analyzed, and presented as a list of recommendations or suggestions that are possible to be implemented. Moreover, it is advised to divide the data into two different kinds, quantitative and qualitative. In order to calculate the different types of usability metrics, for example, success or completion percentage, satisfaction ratings, the time taken to complete a task, and the number of errors made by users, it is recommended that quantitative data be utilized. In order to compile insights in regard to which paths or patterns were followed or used by users within the usability testing, the obstacles that were faced during the usability testing, and the responses which were given within a posttest, it is recommended that qualitative data be utilized.

This research is largely qualitative. The data needed is qualitative and will be collected based on verbal details. However, there is also quantitative data that exists within the data set that will be extracted through usability metrics and a questionnaire. In this research, I make use of multiple data collection techniques as well as various methods of analysis and presenting results. Therefore, this research is placed within the mixed-methods research choice.

6. Research Time Horizon

Any research can have two time horizons [1]. The two time horizons can be distinguished through the following question: "*Is the research a 'snapshot' taken at a point of time or is it a series of snapshots over a given period?*"

The time horizon can be defined as a specific period of time that is covered by a study alongside the time that data were collected and related analysis was conducted. A single snapshot in a specified period of time is named a cross-sectional time horizon, while a longitudinal time horizon has multiple snapshots over a certain time period [43]. A cross-sectional time horizon assists in capturing the immediate link among causes and effects while a longitudinal time horizon assists in capturing the changes and in testing the constancy of the inferences over a period of time.

This research has a cross-sectional time horizon. Usability testing is used to reveal the relationships between various features of IoT-enabled mobile apps and their effects on the apps' usability. Experimental studies are usually done as a snapshot to find the cause and effect of certain features.

7. Research Techniques and Procedures

In this part, three primary inquiries will be discussed:

(i) What methods are utilized in order to collect data
(ii) From which sources the data are collected
(iii) How to analyze the obtained data

Usability testing is the information system's evaluation [44]. It involves three techniques [45]:

(i) Observing participants while they are performing a task
(ii) Asking participants to think aloud while they are performing a task
(iii) Asking participants questions to probe about the task

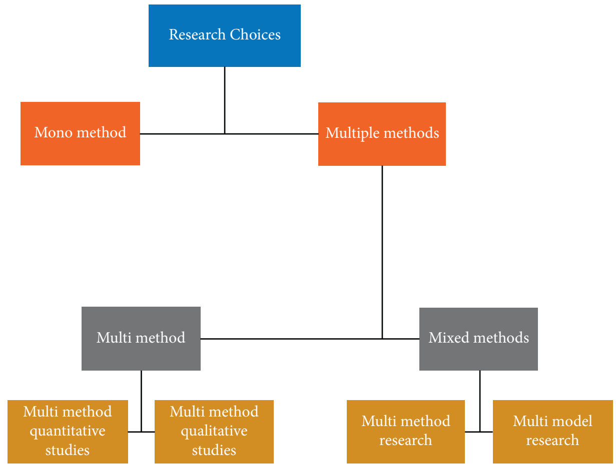

Figure 6: Option for research choices.

Table 2: Explanation for research choices.

Choice	Description
Monomethod	Uses only one method of collecting data and procedure for its analysis that are corresponding
Multimethod	A combination of different techniques of data collection that is either qualitative or quantitative
Multimethod quantitative study	Involves more than one quantitative technique for collecting data and doing analysis
Multimethod qualitative study	Uses multiple qualitative techniques for collecting data and doing analysis
Mixed methods	Uses both quantitative and qualitative techniques for collecting data and doing analysis
Mixed-model research	A mixture of data collection strategies that are both qualitative and quantitative and used for analysis
Mixed-method research	Involves both qualitative techniques and quantitative techniques for collecting data and analyzing procedures either in parallel (same time) or sequential (one after another)

According to [46], usability testing is an empirical data collection process that observes users while they are completing a certain task with the app under evaluation. Usability testing methods fall into two categories: analytical (a user is present who is not involved) and observation (the user is involved) [47]. In this research, I use the observation method of usability testing. Placing the user in front of the apps and observing them perform tasks are useful in evaluating an app's design because this allows the person conducting the usability test to examine the problems users are facing when a service or product is being used [48].

8. Challenges and Utility of the Usability Methods

This research work includes some challenges. There is a lack of synchronization between the available IoT-enabled apps to evaluate and compare their performance. Each kind of app has several features that might not be included in the other apps. Due to the lack of similarity between apps, it is difficult to undertake a performance evaluation of each app. In addition to this, there might be a need to have certain skills or mobile devices to use such apps. Thus, it is very important to take into account the feedback from the target users in terms of how each app was rated. Furthermore, since a user's experience might change when changes are made with new versions of apps, usability testing techniques can help to understand users' experiences. Without any feedback from users, app developers find it difficult to identify the shortcomings, loopholes, and drawbacks in their apps. Prelaunch or pilot studies have their own benefits but in usability testing their benefits are limited as they lack the ability to identify the limitations and challenges of apps in an exhaustive manner. Usability testing methods are useful because they can address the limitations and challenges of various apps [49].

In this study, I include the following usability methods: interview, observation, think aloud, and usability metrics. The interview methodology helps in understanding the users' perceptions of IoT-enabled apps and allows observers to learn about their experience without the alteration of users' perceptions. The think-aloud method is chosen because it benefits our understanding of the users' experience with IoT-enabled apps. It allows the observer to know users' opinions regarding the design elements within an app's user interface (UI).

Testing through observation assists in removing the self-reporting errors that arise due to the observer's impact upon users' thinking process and perceptions. The main benefit of this method is that the user has the freedom to use the product without the observer's interference. The usability metrics method measures the seven usability attributes (effectiveness, efficiency, satisfaction, cognitive load, errors, learnability, and memorability). Through their quantitative results, a comparison can be made between the tested IoT-enabled apps to determine the level of usability [50, 51].

Therefore, the different usability testing methods each have their own advantages. In this study, their combination will help us study the usability and features of IoT-enabled apps through direct observation of and interaction with participants.

9. Conclusion

It not easy to determine the method and procedures that should be applied in order to successfully obtain findings. This is because each kind of research can have various approaches that a researcher can use. Hence, this study aims to facilitate developing a deeper understanding of how to correctly determine which methods and techniques one can apply while performing an experiment. This paper focuses on the research online framework and how it can be integrated with an IoT-enabled mobile app. Future work will focus on integrating more advanced technology such as artificial intelligence (AI) and machine learning (ML) with the research onion framework.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

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Research Article

Factors Influencing the Information Service Quality of the Online Website of Hospitals in China

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Internet's online information services can deliver high-quality services to the public while eliminating social alienation and virus transmission. From 2013 until the fourth quarter of 2020, China has had the highest number of Internet users in the world. Public access to information in the health care business in China is mostly through the Internet. In the healthcare business, high-quality information services are the fundamental obstacle because of their importance and effect on human lives. This article uses Chinese hospitals as a case study, covering assessment system development and empirical research. A total of 217 questionnaires were issued, 212 of which were valid, and the effective rate was 97.6 percent. The outcomes of the research show that the extensive epidemiological information services of the hospital website during an epidemic outbreak have a significant influence on the public's use of the hospital website. Secondly, high-quality epidemic-related information services are critical to enhancing website information services during outbreaks. Finally, in the epidemic, the high-quality service of the hospital's website has a greater impact on the worth of information in comparison to the content of information service.

1. Introduction

As per the China Internet Network Information Center (CNNIC 2019), there were 1.701 billion Chinese Internet users as of June 2019. In China, it has become the major source of news for the population [1]. Coronavirus disease (COVID-19) is a global public health emergency, as of January 30, 2020, according to the World Health Organization [2]. According to the World Health Organization, as of April 18, 2020, the virus had infected 2,310,572 individuals, killed 158,691 people, and is currently spreading. A worldwide pandemic has been triggered by the coronavirus (COVID-19), which has spread to other nations, including mainland China [3]. This virus can be prevented by avoiding contact with the virus. It may be prevented most effectively by avoiding active or passive exposure to the viral environment, according to China, the US Centers for Disease Control and Prevention, and the World Health Organization [4]. All of these methods have had a positive impact on preventing epidemics. The Chinese hospital's Internet website was used by many locals during the outbreak of the coronavirus (COVID-19) to get health and information services. Aside from the lack of study, it is unclear which elements would impact the quality of public information services on hospital websites during the pandemic.

The theoretical research platform of this study is constructed based on the initial detailed indicators of the evaluation system set mentioned previously after reviewing related theories such as the two-dimensional model of perceived quality, the model of customers' perceived service quality, SERVOUAL model, E-SQ, and OSQ. The medical information service quality of the hospital online website is jointly determined by perceived service quality and the evaluated quality of platform information. Interaction, online medical service, platform information construction, and platform information quality are four dimensions used for evaluating the perceived quality of medical information service of the hospital's online website.

In this study, the full score represents the customer's expected service quality, while the perceived service quality score is the difference between the expected and actual service quality. The major contribution of the paper is to provide advanced comprehensive epidemiological information services of the hospital website during a pandemic outbreak and, secondly, what affects the service quality of the hospital's online website during the COVID-19 epidemic. Thirdly, we quantitatively evaluate the service quality of the hospital's online website. Lastly, a strategy for improving the quality of hospital information services during an epidemic outbreak has been proposed utilizing network data from the hospital's online domain.

The rest of the paper is organized as follows. In Section 2, the research methodology is proposed. The performance evaluation system analysis is conducted in Section 3. The experimental results and discussion are further summarized in Section 4. Finally, Section 5 concludes the paper with a summary and future research directions.

2. Research Methodology

In recent years, there are many studies on the website information service. Most of them have a very direct relationship with the dimensions and attributes of the information service quality of online websites. These studies present the medical information service quality indicators of hospital online websites. These studies not only make contributions to the information service quality attributes and dimensions but also provide further studies with theoretical basis and cases. For instance, some scholars can discuss website online websites in hospitals that render both information resource service and general online service. We uncover the medical information service quality indicators of hospital online websites from the following studies.

A number of authors have proposed stage models; for example, electronic service quality (E-SQ) was defined by Parasuraman et al. [5] as the degree to which consumers can acquire and provide items or services via the Internet efficiently and effectively. Cai and Jun [6] define online service quality (OSQ) as the gap between customers' perceived and anticipated service. Webqual (Web Quality) is described by Jeon [7] as the quality of Internet technology activities. Xie et al. [8] provide an online information service. Reliability, convenience, communication efficacy, tangibles, dependability, prompt responsiveness, and consistency are all important considerations. Kolesar and Glbraith [9] described the service for online purchasing using tangibles, dependability, reactivity, and ease of use. Zeithaml et al. [10] described the service provided electronically with efficiency, dependability, and secrecy are all important considerations. Wolfinbarger and Gilly [11] described the service for electronic retail. Website design, dependability, and service security are all important considerations. Hung [12] defined website quality as "the overall quality of the website, the quality of the information, and the quality of the service." Harold and Linda [13] evaluated the quality of website services. Many more researches [14–25] focused on online marketing, credibility, service dependability, and communication, as well as user satisfaction, availability, characterization, information quantifying, and privacy, quantifying the quality of hospital online service providers.

2.1. Website Service Quality. The total information service quality of the hospital on the website is derived from the patient's perception of service quality on the hospital website and the information quality measured by the information service quality assessment system. According to the theoretical model in Figure 1, this research acquired the dimensional structure of the Chinese hospital information service quality evaluation system during the (COVID-19) pandemic after two rounds of an expert consultation. Figure 1 depicts the eight parameters for evaluating the information quality of an online website.

$$\mathrm{FR} = \sum_{\mathrm{i}=1}^{W} \sum_{\mathrm{j}=1}^{S_{\mathrm{i}}} \mathrm{W}I_{\mathrm{ij}} SD_{\mathrm{ij}} \times 100. \tag{1}$$

2.2. Measuring Web-Based Service Quality. The information service weights and quantitative values of the online website during the COVID-19 pandemic were developed by weighing the quantitative numerical weights of the information service system assessment and talking with experts via surveys. Based on the aforesaid model, standards for Chinese hospitals and the COVID-19 pandemic Chinese hospital Internet website Information service complete assessment model and the calculation formula for the weighted total score were created. Equation (1) depicts the calculating formula.

The FR in the formula represents the final quantitative score, and the value of FR ranges from 0 to 100. The score of FRij is the score obtained by the j^{th} index in the i^{th} dimension. WI_{ij} represents the weight of the j^{th} index in the i^{th} dimension. The value range of i is the maximum value of m and the minimum value is 1, and the value range of j is the maximum value of n_i and the minimum value is 1. Si represents the number of indicators in the i^{th} dimension, and W represents the number of dimensions. W is equal to 8. S is the total number of three-level indicators in the evaluation system, equal to 55.

3. Performance Evaluation System

In this section, we create a quality assessment framework for web-based service quality by learning from the previous design and taking into account the distinctions between web-based services and conventional services. The comprehensive weight and calculation method of indicators of the China online hospital information service evaluation system are shown in Figure 2.

4. Result and Discussion

4.1. Data Collection Procedure. This empirical study will explore and assess the hospital's website. During the outbreak of coronavirus (COVID-19), on March 1, 2020, the hospital's website began reporting and providing services for coronavirus (COVID-19) information. This article covers the time node for reporting and servicing on the hospital website in this empirical investigation. Against the backdrop of the epidemic, nine empirical research surveys and data

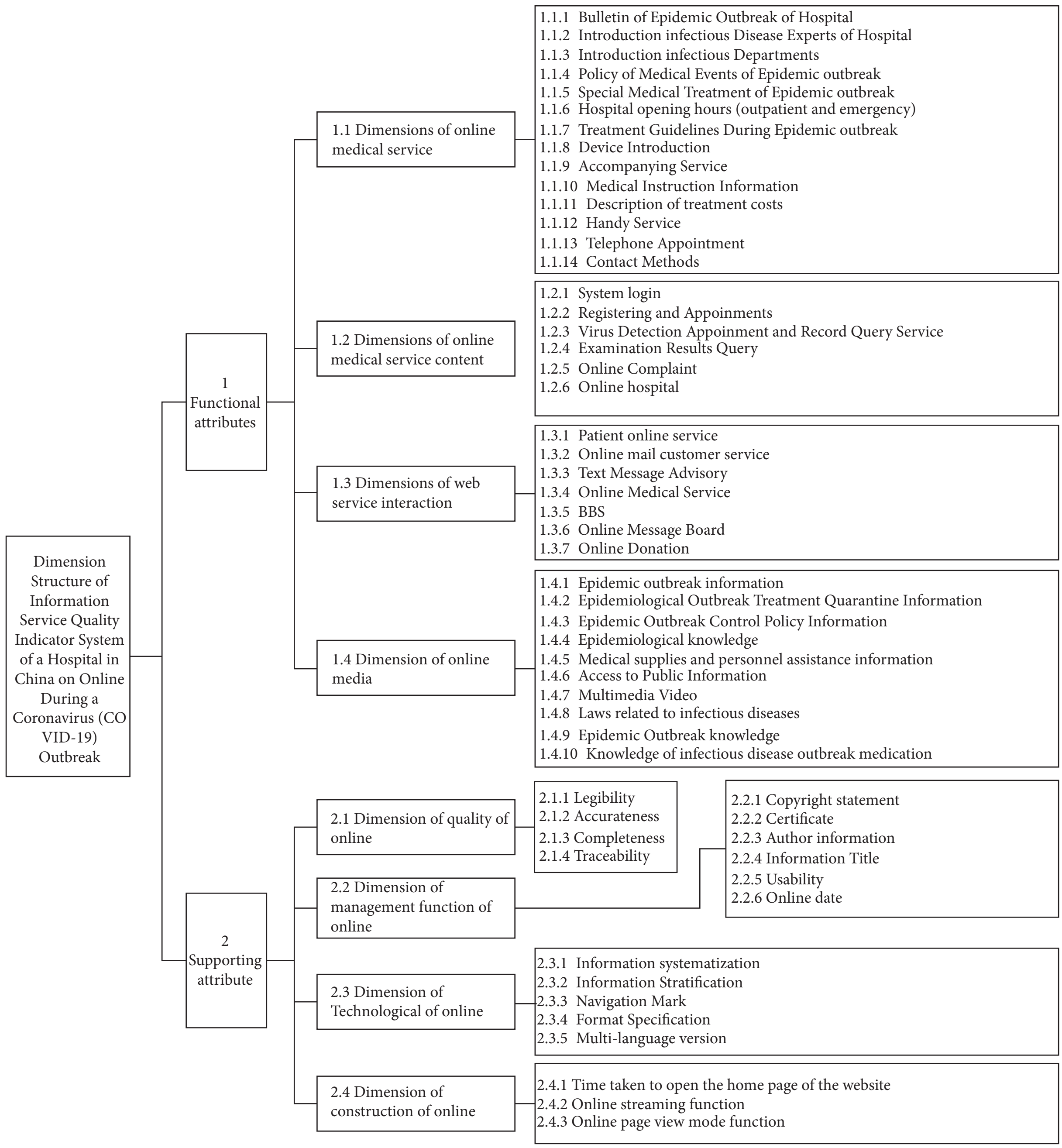

Figure 1: Dimension of a Chinese hospital on online service during the outbreak of coronavirus (COVID-19).

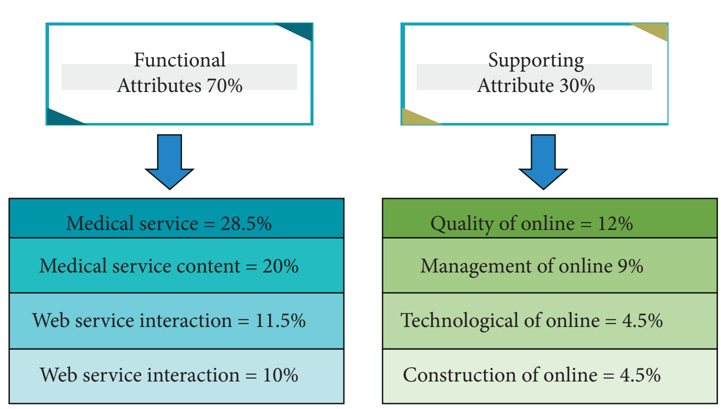

Figure 2: Comprehensive weights of indicators of China's online hospital information service evaluation system during the coronavirus (COVID-19) outbreak.

Table 1: The composition of participants in the empirical research on the comprehensive evaluation system.

Dimension	Item	Number	Percentage (%)
Users	Outpatient	18	25
	Inpatient	18	25
	Hospital employee	18	25
	The public and professionals	18	25
Gender	Male	42	58
	Female	30	42
Age	16–21	2	3
	22–27	20	28
	28–33	30	41
	Over 34	20	28
Education	College	20	28
	Bachelor's	30	42
	Master's or above	18	25
	High school or lower	2	5

Table 2: Evaluations of a hospital in China online during the coronavirus (COVID-19) outbreak.

No.	Date	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	Total score
1	2020/2/3	10.952	11.800	0.540	0.000	1.683	1.731	1.575	2.934	31.215
2	2020/2/10	13.607	11.800	1.860	0.000	1.785	1.731	1.575	2.934	35.292
3	2020/2/24	16.938	12.994	5.560	2.536	1.785	1.731	1.575	2.934	46.053
4	2020/3/2	18.488	12.994	5.560	2.536	1.938	1.731	1.575	2.934	47.756
5	2020/3/16	18.850	12.994	5.920	3.935	1.785	1.731	1.575	2.934	49.724
6	2020/3/30	18.850	12.994	5.920	3.935	4.418	4.881	1.527	2.934	55.459
7	2020/4/6	18.850	12.994	5.920	4.526	6.821	4.881	1.575	2.934	58.500
8	2020/4/13	18.850	12.994	6.800	4.526	7.541	5.637	1.728	3.380	61.455
9	2020/4/27	18.850	12.994	6.800	5.561	10.169	5.934	1.728	3.380	65.415

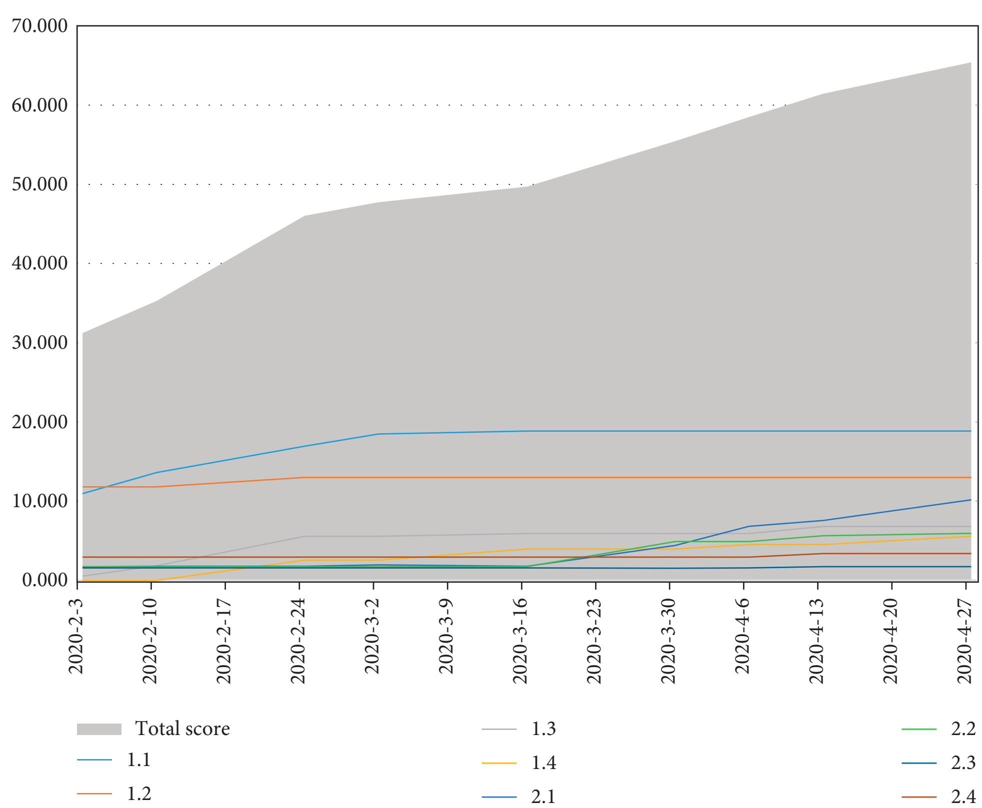

Figure 3: Correlation analysis of evaluations of a hospital in China online during the coronavirus (COVID-19) outbreak.

Table 3: Correlation analysis of information service and the traffic of a hospital in China online during the coronavirus (COVID-19) outbreak.

Correlation analysis object	Pearson correlation	Sig (2-tailed)	Correlation	N
Research findings and total traffic	1.000	0	Correlation is significant at the 0.01 level	18
Research findings and PV	1.000	0	Correlation is significant at the 0.01 level	18
Research findings and UV	1.000	0	Correlation is significant at the 0.01 level	18

Table 4: Score of a hospital online website in China of growth of rate during the coronavirus (COVID-19) outbreak.

Date	1	2	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	Total score
2020/2/3	0	0	0	0	0	0	0	0	0	0	0
2020/2/10	1.17	1.01	1.24	1.00	3.44	0	1.06	1.00	1.00	1.00	1.13
2020/2/24	1.39	1.00	1.24	1.10	2.99	0	1.00	1.00	1.00	1.00	1.30
2020/3/2	1.04	1.02	1.09	1.00	1.00	1.00	1.09	1.00	1.00	1.00	1.04
2020/3/16	1.05	0.98	1.02	1.00	1.06	1.55	0.92	1.00	1.00	1.00	1.04
2020/3/30	1.00	1.71	1.00	1.00	1.00	1.00	2.47	2.82	0.97	1.00	1.12
2020/4/6	1.01	1.18	1.00	1.00	1.00	1.15	1.54	1.00	1.03	1.00	1.05
2020/4/13	1.02	1.13	1.00	1.00	1.15	1.00	1.11	1.15	1.10	1.15	1.05
2020/4/27	1.02	1.16	1.00	1.00	1.00	1.23	1.35	1.05	1.00	1.00	1.06

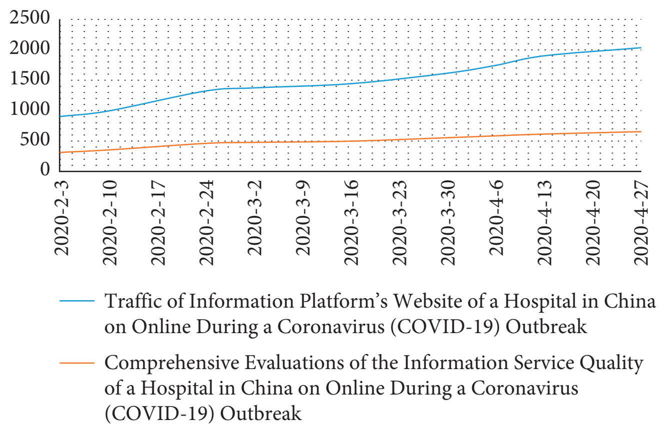

Figure 4: Line chart of the correlation analysis of the online website of a hospital in China during the coronavirus (COVID-19) outbreak.

collecting were conducted on the redesigned hospital website, thus increasing the comparability and scientificity of the empirical research survey results presented in this paper.

4.2. Identification of Important Attributes and Dimensions. Participants of the empirical research are selected according to the principles of randomness, feasibility, and objectivity. This article selects participants based on the principle of stratified random sampling and is divided into hospital outpatients, inpatients, staff, public, and professional service personnel based on the principle indicators (including random users, management majors, professors, and website designers). For the composition of participants, see Table 1.

From February 2020 to April 2020, 72 study participants used Internet Explorer 11 as their browser and visited the hospital information website at nine different time points. In this study, the study participants were selected using a stratified random sampling method. Based on the sampling indicators, the participants were divided into four groups: outpatients, inpatients, hospital staff, and the public and professionals.

4.3. Factor Analysis. A detailed review of hospital information services was carried out as part of this research. If the assessment ratings of the participants are considerably different, the average value will be utilized to determine the final result for each participant. As a whole, the averages are as follows: 31.215, 35.292, 46.053, 47.756, 49.724, 55.459, 58.500, 61.455, and 65.415. Researchers found that, after adding information and services regarding the coronavirus (COVID-19) epidemic, the hospital's online site got a more complete review of its information services as shown in Table 2 and Figure 3.

Through the binary correlation in the R programming language, the author conducted a comprehensive evaluation of data of the online website and the flow data of the hospital online website. Table 3 shows the correlation analysis of

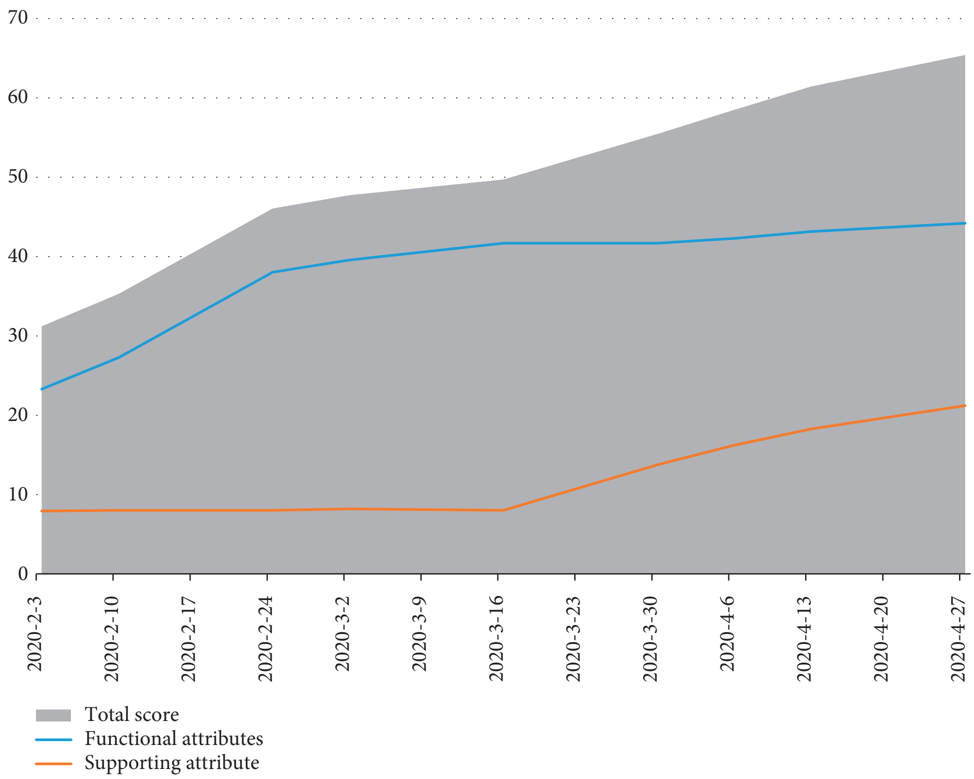

Figure 5: Line chart of the functional quality attributes and supporting attribute.

information service and the traffic of a hospital in China online during the coronavirus (COVID-19) outbreak. PV is a comprehensive evaluation of data of the online website. UV is flow data of the hospital's online website. The correlation coefficient between the two is 1, and we can see from the correlation coefficient that this is a very obvious correlation.

There is a favorable correlation between the overall evaluation of hospital online services and website traffic in this study, and the number of visits changes as the overall rating of services changes as well (see Table 4 and Figures 4 and 5 for details). As a result of this, from March 30 to April 27, 2020, we can observe that improvements in information service function attributes are more rapid than improvements in supporting attributes. If you are looking for a way to improve your services from March 30 to April 27 of 2020, the hospital's information services will be a great place to start! From February 3 through March 16, 2020, you can visit the hospital's website online. The improvement rate of the information service function and support attribute of the hospital website tends to be consistent, and even the support attribute is slightly higher than the function attribute.

5. Conclusions

Ensuring effective and efficient management for quality and patient safety is still in its infancy despite increasing pressure on organizations to better and emerging evidence that better board supervision is connected with a higher level of care. Based on the empirical research data and analysis in this article, we calculate the functional quality of the information services of epidemic-related websites on April 27, 2020. The final score was 44.21, which was 1.9 times the original score of 23.29 on February 3, 2020. This reflects the improvement of the function of information services. Enriching information services on epidemic-related websites is the key to improving website information services during epidemic outbreaks. The evaluation scores of information services of epidemic-related websites have increased by 2.1 times, among which the scores of functional attributes of information services have been increased by 1.9 times and the scores of supporting attributes evaluation have been increased by 2.7 times. Moreover, the support attributes of information services for epidemic-related websites will be an important direction for the hospital to improve the quality of services in the next stage. Furthermore, the support characteristics of information services for epidemic-related websites will be an essential path for the hospital to improve service quality in the future.

Data Availability

The survey results and network traffic data used to support the findings of this study are available from the corresponding author upon request

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

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Research Article

Human Resources Balanced Allocation Method Based on Deep Learning Algorithm

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At present, the economics and social developments show the characteristics of diversification, and the focus of social enterprise management is driven by the allocation of human resources. Human resource allocation is a way of appropriate allocation and reasonable placement of human resources. It means that, under the guidance of science, human resources can maintain the best combination with other resources at any time. Nevertheless, the irregularities in management teams and the balanced differences of talent quality have a great effect on the balanced development of an enterprise. Based on this, this paper studies the establishment of a recurrent neural network (RNN) model to realize the allocation of human resources and the balanced development of enterprise management. Firstly, a deep learning model, based on the recurrent neural network, is established. Then, the human resources data is analyzed to calculate the matching degree between the human resources and posts. Finally, personnel scheduling is carried out according to the matching degree score between the human resources and posts, to obtain the optimal balanced allocation result of the human resources. Experimental results show that our method can bring significant improvements to personnel position matching and effectively enhance the efficiency of human resource allocation based on the cloud environment.

1. Introduction

The term "human resource" refers to the sum of the labor capacity of workers in a specific field. There are many influencing factors on social productivity, and human resource is the most active and positive factor, which is the root of the existence and growth of a social organization [1]. In recent years, China's economy has gradually entered the "new normal." This is well known that advanced enterprise management methods and whether they can give full play to the value of employees have become important evaluation criteria for enterprise resource innovation and competitive advantage [2]. The human resource management personnel of the engineering unit shall analyze the ability of the unit's employees, allocate human resources reasonably, and form a working state of combining strength and weakness [3]. The optimization of human resource allocation is mainly divided into (i) establishing the idea of optimal allocation of human resources; (ii) updating the organizational structure; (iii) clarifying the position authority; (iv) integrating management methods; (v) providing effective guarantee for position management; and (vi) strengthening targeted training [4]. The formulation and implementation of human resource management policies are not effective, which has seriously affected the operation of modern enterprises. Therefore, the scientific and reasonable human resource allocation method is the sword of enterprise management.

At present, the computing models applied in the field of human resources are usually based on statistical algorithms, which cannot meet the processing needs of massive data and do not consider the characteristics of data hiding, which easily leads to the problem of lack of information [5]. Among the classical assignment algorithms, there is a quantitative assignment algorithm [5, 6]. Individuals need to complete M

tasks ($n \neq m$ is allowed), establish a mathematical model based on the operational research method, and then obtain the assignment scheme based on the Hungarian method. However, the algorithm has some limitations when applied to practical work. This algorithm requires that the factors which determine the nature of different tasks are single and the same. If there are two or more different tasks in this m task and the influencing factors are not single, then the efficiency index we need cannot be established through this algorithm. Therefore, the application of this algorithm in human resource allocation cannot be popularized [6]. As a result, this paper comprehensively considers several cases and selects the recurrent neural network algorithm to reasonably allocate human resources, that is, calculate and recommend human resources matching posts through the algorithm.

To improve the human resource system, this paper mainly solves the matching problem between the human resources and posts. Therefore, the input of the recommendation algorithm is the personal identity information of human resources, and the output is the position suitable for their identity. The dataset of the model contains numerous parameterized information such as human gender, personality, and professional qualifications, and the mapping dataset contains the parameterized information of the corresponding position. The human resource allocation problem to be solved in this paper is simplified to the problem of taking the given parameterized manpower as the input and calculating the predicted output through the algorithm. The major contributions of our work are as follows:

(i) We propose a new method to establish a recurrent neural network (RNN) to identify the allocation of human resources

(ii) A deep learning model based on a recurrent neural network is designed; then the human resources data are analyzed to calculate the matching degree between human resources and posts

(iii) Finally, the personnel scheduling is carried out according to the matching degree score between human resources and posts

The remainder of this paper is organized as follows: in Section 2, we introduce the related work. In Section 3, we introduce the methodology of our proposed model. In Section 4, we conduct experiments on a real-world dataset and compare the outcomes with some existing methods. Finally, we conclude the paper in Section 5 and offer several directions for future research.

2. Related Work

Human resource allocation is the corresponding recommendation and mapping between the human resources and posts. The application of the suggested recommendation algorithm can solve the problems described in this paper. A reasonable and applicable recommendation algorithm could potentially improve the efficiency of the balanced allocation of human resources. In recent years, recommendation algorithms have been widely used in many Internet enterprises. A complex and effective recommendation algorithm can mine users' multimodal information through users' history records and platform information, analyze users' various characteristics, predict people's preferences, accurately and intuitively analyze users' preferences, and push appropriate information to the users.

Compared with the existing traditional recommendation algorithms, deep learning series algorithms have strong advantages in the automatic extraction of abstract features. In recent years, with the rapid development of human electronic information technology, big data processing has been greatly improved, which also makes deep learning development rapidly and widely used in various domains [7]. In the following years, a series of deep learning algorithms have sprung up one after another. In 2006, based on the existing deep learning theory, Hinton et al. of the University of Toronto successively studied the relevant theories of Boltzmann machine and neural network [8]. The deep learning algorithm proposed by their team has achieved good results in terms of data classification and prediction. Then, in 2007, the authors in [9], developed a collaborative filtering algorithm based on the restricted Boltzmann machine (RBM), which is a generative stochastic neural network to train the scoring matrix of the visible layer data. Then, the trained model is used to predict users' preferences. At that time, SVD + + was the core of a series of deep learning models [10]. Due to its limitations, the series of algorithms almost fell into a deadlock. It was not until the emergence of RBM that the situation improved. When RBM appeared, the authors improved this series of depth algorithms and proposed RBM as a comprehensive generalization of the deep Boltzmann machine (DBM) [11], which is the first real depth learning model. Then, Netflix researchers studied the combination of GPU and AWS and introduced the distributed neural network theory [12]. After that, Spotify music company applied it to the music style analysis of users and made personalized recommendations according to the user's preferred song style, which once caused great repercussions [13]. In the deep learning model, the historical records of platform users can be regarded as a periodic series of data [14, 15]. To analyze these time series data, various methods based on recurrent neural network (RNN) are preferred in the existing state-of-the-art literature [16]. As the founder of this usage, Netflix applied RNN to video recommendation systems, which promoted the research of deep learning algorithms of other companies and achieved significantly good and outstanding results.

Through the above research on the current situation at home and abroad, it can be concluded that the deep learning and recommendation algorithms have a mature development path [17]. After several updates and iterations, their applications have been widely used in both video and music recommendation, better match the user and system data, and recommend a better individual matching mode as compared to what was already available in the market. Similarly, applying this recommendation algorithm to job recommendations can complete the systematic, reasonable, and unbiased deployment of human resources. In this paper, the recurrent neural network model is used to learn the post manpower matching set and obtain a deeper post preference representation containing more useful information. This information can be used for the subsequent recommended posts and manpower matching.

3. The Proposed Methodology

According to the traditional human resource allocation theory, planning human resources is mainly to analyze the personnel structure of the unit, and sort out the relationship between post demand and personnel ability in detail. Personnel ability includes many elements. These elements are weighted and summed to judge the quality score of the personnel. The traditional human resource (HR) scoring process is shown in Figure 1.

Firstly, the received data is grouped and analyzed. The data grouping includes the personnel evaluation matrix and personnel capability matrix. The most widely used is to establish an employee ability evaluation matrix, which may consider many factors, such as self-evaluation, superior and subordinate evaluation, and patient evaluation. The personnel capability matrix includes employee performance, attendance rate, professional title, and other information. After the personnel evaluation matrix value and personnel capability matrix values are obtained, the key manpower and position matching degree can be obtained by the formula as illustrated in the following:

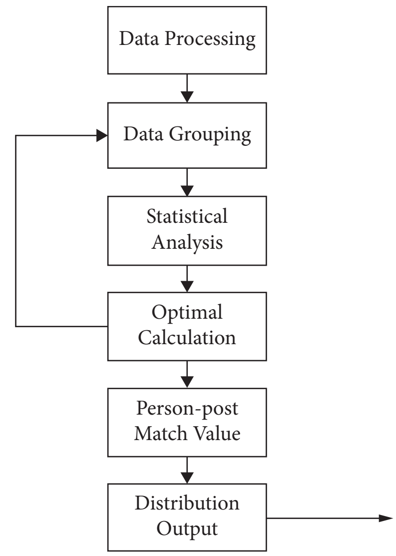

Figure 1: The human resources matching process.

$$\left(H_{ij}\right)_{p\times q} = \left(n_1\left(a_{ij}\right)_{p\times 1} + n_2\left(b_{ij}\right)_{p\times 1} + \cdots + n_4\left(d_{ij}\right)_{p\times 1}\right), \tag{1}$$

where $n_1 \sim n_4$ is the corresponding evaluation parameter. Let another variable be X_{ij}, we have

$$X_{ij} = \begin{cases} 1, & \text{arrange personnel to corresponding positions,} \\ 0, & \text{no personnel will be assigned to the corresponding positions.} \end{cases} \tag{2}$$

Therefore, the personnel can be optimized by the manpower and position matching degree model:

$$\begin{aligned} &\max\left(Z = \sum_{i=1}^{n}\sum_{j=1}^{n} s_{ij}X_{ij}\right), \\ &\sum_{i=1}^{n} X_{ij} = 1, \quad i \text{ and } j = 1, 2, \ldots, m, \\ &\sum_{i=1}^{n} X_{ij} \leq 1, \quad i \text{ and } j = 1, 2, \ldots, n. \end{aligned} \tag{3}$$

The above algorithm is simple and effective and can better configure human resources, but it is only applicable to the case of less human data. With the increase of hospital system, human data is also increasing, and the problem has become complex. This method has low computational efficiency, cannot mine data well, and cannot manage human resources effectively.

It can be seen from Figure 1 that the essence of the human resource scheduling model is to analyze human resource data and calculate the matching degree between the human resources and positions. Afterward, personnel scheduling is carried out according to the matching degree score between the manpower and position, which can be abstracted into a recommendation model in essence. Recommendation models have been analyzed and verified in many fields. At present, the mainstream recommendation models use a recurrent neural network as a primary and most important data processing module [18].

It should be noted that RNN records different historical information of time series data through the cyclic structure in the model. Its structural characteristics lead to its great advantages in processing various time series data. Different from ordinary neural networks, the hidden layers of recurrent (cyclic) neural networks are connected; that is, the output at the current time is not only related to the current input but also related to the output of the hidden layer at the previous time. The RNN model is shown in Figure 2. Among them, vector X, vector S, and vector O represent the input data, hidden layer value, and output data in turn. Similarly, U and V represent the weight matrix from the input layer to the hidden layer and the weight matrix from the hidden layer to the output layer in turn. The value S of the hidden layer depends not only on the value of X but also on the value of S of the last hidden layer. The weight matrix W is the last value S, as shown in Figure 2, and denotes the input of this time.

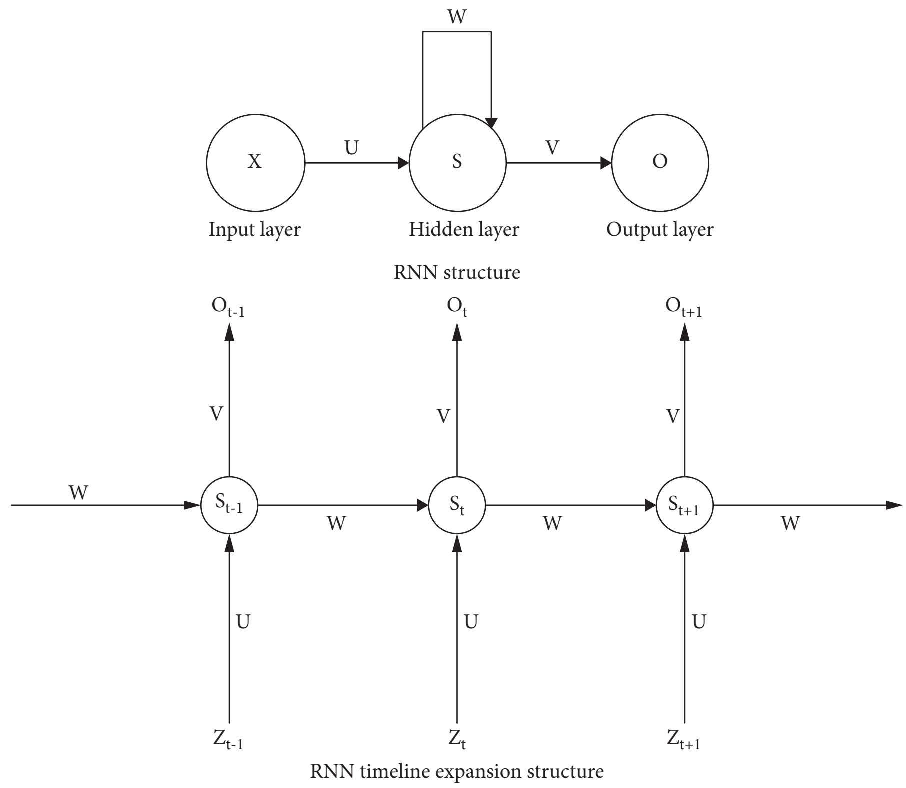

Figure 2: The RNN structure understanding diagram.

The network expanded in Figure 2 is the model at the time t, and the symbol correspondence is as follows: z_t represents the input of input layer, s_t represents the output of hidden layer, g_1 represents activation function of the output layer, f_1 represents activation function of the hidden layer, and o_t represents the output of output layer. It is worth noting that the value of s_t depends on z_t as well as s_{t-1}. The forward calculation formula of the cyclic neural network is as follows:

$$o_t = g_1(Vs_t), \tag{4}$$

$$s_t = f_1(Uz_t + Ws_{t-1}). \tag{5}$$

Equations (4) and (5) are used for cyclic iterative calculation, and the results are as follows:

$$\begin{aligned} o_t &= g_1(Vs_t) \\ &= g_1(Vf_1(Uz_t + Ws_{t-1})) \\ &= g_1(Vf_1(Uz_t + Wf_1(Uz_{t-1} + Ws_{t-2}))) \\ &= g_1(Vf_1(Uz_t + Wf_1(Uz_{t-1} + Wf_1(Uz_{t-1} + \ldots)))). \end{aligned} \tag{6}$$

As can be seen from equation (6), the current time not only records the current time information but also contains historical information, which shows that the cyclic neural network has the function of memorizing historical information. However, the traditional cyclic neural network always calculates the state of the model by covering layer by layer. This method has some disadvantages. The chain rule of derivation is used for checking. This method directly leads to the function gradient expressed in the form of continuous multiplication, which makes the model have the fault problem of gradient disappearance.

The main feature of the recurrent neural network is to use cyclic convolution for data training operation. The cyclic convolution network model can be regarded as a hierarchical data model, and the input of the convolution network is the original human resource data. Through the processes of cyclic convolution, pooling, and activation function, the abstract features between data are extracted. The process expression is as follows:

$$\begin{aligned} & x^1 \longrightarrow \omega^1 \longrightarrow x^2 \longrightarrow \cdots \longrightarrow x^{L-1} \longrightarrow \omega^{L-1} \\ & \quad \longrightarrow x^L \longrightarrow \omega^L \longrightarrow z, \\ & z = f\left(x^L, y\right), \end{aligned} \tag{7}$$

where x^L is the data input of L layer, ω is the parameter weight value of L layer, z is the loss function selected by the model, y is the calibration value of the model, and f is the final calculation parameter of the model. This paper improves the basic neural network, uses the hybrid cyclic neural network model, and uses the combination of global model and local model to take the data characteristics after hierarchical operation of the model as the network output, to realize the data processing. Then, the hierarchical model structure is used to build the network, to realize the matching recommendation of manpower and position.

In the process of building the model, the cross entropy is selected as the judgment loss function. The loss function can compare the actual value of the data with the expected value of the data to determine the proximity of the data. The loss function is as follows:

$$L = -\sum_{n} (y \log p + (1-y)\log(1-p)). \tag{8}$$

At the same time, the gradient optimization algorithm is used to optimize the parameters during training. In this way, the parameter transfer can be as accurate as possible. The specific update process of model parameters is as follows:

(1) Update the number of iterations and learning efficiency of the neural network:

$$\begin{aligned} m_t &= \beta_1 m_{t-1} + (1-\beta_1) g_t, \\ v_t &= \beta_2 v_{t-1} + (1-\beta_2) g_t. \end{aligned} \tag{9}$$

Among them, β_1 and β_2 are the hyperparameters of the cyclic neural network, g_t is the calculation gradient of the model, and t is the number of iterations of the model.

(2) Optimize the orientation of the first-order estimate and the second-order estimate, including

$$\begin{aligned} \widehat{m}_t &= \frac{m_t}{1-\beta_1^t}, \\ \widehat{v}_t &= \frac{v_t}{1-\beta_2^t}. \end{aligned} \tag{10}$$

(3) Update the parameters of the model from the results obtained above:

$$\theta_{t+1} = \theta_t - \frac{l\widehat{m}_t}{\sqrt{\widehat{v}_t} + \varepsilon}. \tag{11}$$

Combining the cyclic convolution neural network with the traditional human resource allocation algorithm, a human and post matching recommendation algorithm suitable for the field of human resources is designed in this paper. The algorithm not only improves the problem of low data training quality of traditional algorithms but also effectively improves the data calculation efficiency by using a cyclic neural network. The core idea of the algorithm can be elaborated in three major steps: (i) firstly, the original features in the data are extracted. The original features are consistent with the features required by traditional human resources, including personnel evaluation matrix and personnel ability matrix; (ii) then, the data is extracted to the encoder for coding; and (iii) finally the coding characteristics parameters are input to the input layer of the cyclic neural network. The cyclic convolution layer in the model is used to process the coded data, and then the matching results of manpower and position are obtained. The algorithm flow is shown in Figure 3.

Firstly, data acquisition is carried out, which uses the distributed flow acquisition method to select the data and group it into a personnel evaluation matrix and personnel ability matrix. Then, the data is abstracted, preprocessed, encoded by the encoder, and stored in a data warehouse. The lifting feature algorithm is used to further strengthen the data features and input to the cyclic convolution network. Finally, the matching score between the manpower and position is output, and the human resource recommendation process is completed.

The steps in the algorithm flow are described as follows: the first step is data collection and is categorized as follows:

(1) Data collection: The establishment of an employee position database is the basic work of constructing the deep learning model. Using modern information technology to establish an employee post database system can realize the automation of resource data parameter collection, processing, and management. It makes the statistical data information to steadily improve the results accuracy, preciseness, timeliness, and comprehensiveness. Employee position statistics is mainly used to collect, sort out, and store employee characteristic parameters and position characteristic parameters such as the number and age of various employees in the enterprise or among industries.

(2) Accuracy and timeliness of data: High accuracy employee post statistics can provide an effective guarantee for the human resource allocation system. At the same time, the statistical employee position data is timely, and the lagging database is difficult to match the enterprise information with a high iteration rate.

(3) Data integrity and pertinence: In the process of data collection, the comprehensiveness and integrity of data should be achieved. Based on this, we can get detailed and effective data information from the established database during query or statistics. In addition, whether the statistical data can bring value to decision-making depends on the rational use of the database and the availability of data. Therefore, when designing the database structure, we should consider that the data has the characteristics of comprehensiveness and pertinence, and the database has the characteristics of variable updatable, structure maintainable, fast update speed, and so on. This not only reduces the cost of data collection but also improves the effectiveness of data and effectively ensures the accuracy of the database.

(4) Continuity and nonsystematic structure of the data: In the process of employee position data statistics, we mainly pay attention to two dimensions: time and quantity. On the one hand, it stores the individual personnel status in the database. In addition to the existing status data, it also needs some historical data. These historical data can assist the system to complete the allocation of human resources. Based on the historical data of employees, they can deeply learn their personality characteristics. On the other hand, it saves the basic information of employees based on time series, because the characteristics of

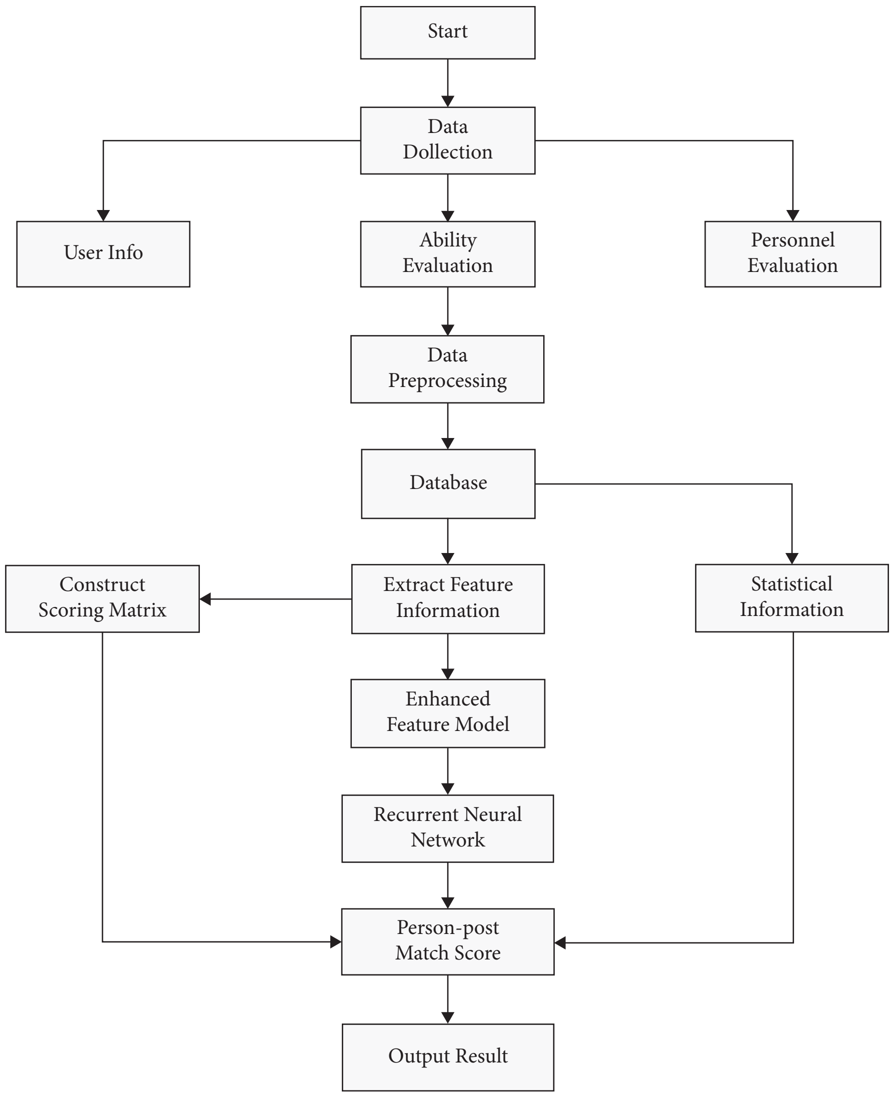

Figure 3: The flow diagram of the proposed algorithm.

employees cannot be judged only by the current data, so it is necessary to obtain the trend from the statistical data. Traditional personnel statistics reports have time records, so it is necessary to save the database based on time series. Therefore, in statistical analysis, by analyzing and comparing the changes of the same index in each period, we can find out the existing problems and put forward corresponding suggestions based on this.

The second step is to preprocess the original data. This step comprises the following substeps:

(1) The difference between data and information: Data and information are very different. The data we count will not be automatically transformed into directly readable information. Data is only a summary in quantitative form. Records in this quantitative form can be sorted into statistical data and become a data resource. From the perspective of statistical methods and thinking, information can be understood as an intermediate medium from data to decision-making. Whether the massive statistical data can play a role in decision-making depends on the rationality of data analysis and sorting. For decision-makers of different events, similarity of statistics, and whether they can extract effective information from the data and whether they can make the extracted information serve their own decision-making reflect the management level of different managers.

(2) Information processing of data: The process of extracting information from statistical data is the process of data processing and analysis. To transform statistical data into information serving decision-making, we must make timely, scientific, and systematic use of the principles, methods, and means of statistical analysis. First, we should ensure the authenticity and reliability of the original data, identify a large amount of data in the statistical data, and prevent forgery, duplication, and disclosure;

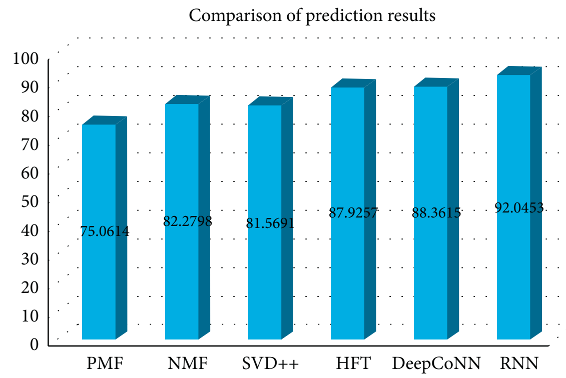

FIGURE 4: Comparison of prediction results.

secondly, strict inspection and control shall be carried out when compiling and sorting statistical data, and the consistency of index meaning and the accuracy of data calculation shall be considered. Finally, form the analysis report.

(3) Supplement and correct the data gap: Supplement and correct the problems encountered in the use of raw data to meet the requirements of management and decision-makers. The need to add and supplement new data depends on their contribution to reducing the uncertainty caused by adverse factors in the decision-making process. Usually, the decision is made when the information is incomplete or asymmetric, so the supplementary data is relatively complete.

The third step is feature enhancement.

Obtain the data from the data warehouse, identify the missing values in the data, delete the harmful data and input the missing values, then normalize or standardize the data, finally learn the data grouping results, and take the fused data as the data input of the network in the model for training.

The fourth step is the output of recommendation results.

Sort the results of the matching degree between manpower and position, output the recommendation results based on the diversity of employee characteristics and position characteristics, and then refer to the score for reasonable position allocation.

4. Results Analysis and Discussion

According to the above methods and algorithm flow, the ideas are sorted out before the experiment. The first is data collection. The distributed flow data collection method is used. Due to the different human data of different enterprises, the format is also different. Therefore, the manpower data must be processed in a unified format, and its data processing methods include discarding, conversion, and other operations. The second is to preprocess the original data. Group the data to get a more comprehensive understanding of the characteristics of the human resource model. At the same time, the data is saved in the data warehouse, which can support the subsequent data model training. Then, feature enhancement is carried out. Obtain data from the data warehouse and learn the data grouping results. The fused data is used as the data input of the network in the model for training. Finally, the recommendation result output. Sort the manpower and position matching results, and then refer to the score for reasonable position allocation.

The experiment will use four publicly accessible data sets from the matching of employees and positions in different enterprises to evaluate the model in this paper. These data sets cover different enterprise fields and contain parametric information of different numbers of employees, positions, and matching relationships. To evaluate the performance of model rating prediction, RNN, and five commonly used recommendation methods are applied to four data sets in different fields and compared. The five recommended models are PMF, NMF, SVD++, HFT, and DeepCoNN. The comparison of the prediction results is shown in Figure 4.

Calculate the accuracy of the above five algorithm models, respectively, take the high-quality manpower and position matching of an enterprise in a quarter as the prediction comparison model, and input the corresponding manpower characteristic parameters and position corresponding parameters. The accuracy of the prediction results is shown in the table. RNN has obvious advantages in accuracy. Comparison of RMSE of different recommendation algorithms is shown in Figure 5.

Finally, as shown in Figure 5, the RNN method in this paper is always better than all the comparison methods. Although comment information is very important in the recommendation process, different ways of using comment information will also lead to different recommendation results. The model based on the recurrent neural network proposed in this paper not only uses comments but also considers the importance of each employee's personality characteristics and professional experience, which further improves the recommendation performance. Statistical table

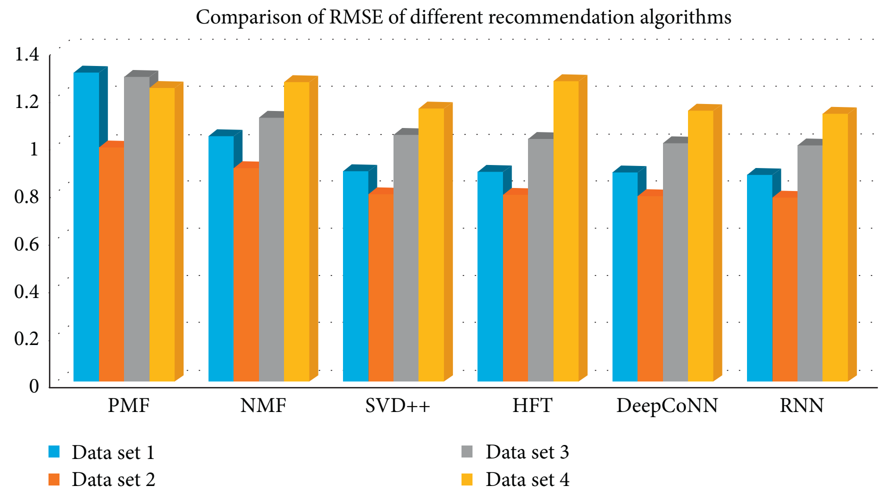

Figure 5: Comparison of RMSE of different recommendation algorithms.

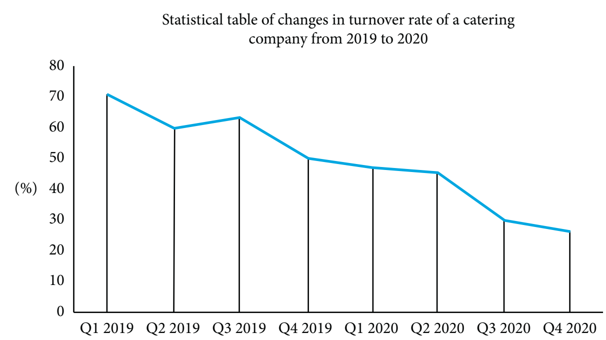

Figure 6: Statistical table of changes in the turnover rate of a catering company from 2019 to 2020.

of changes in turnover rate of a catering company from 2019 to 2020 is shown in Figure 6.

Finally, as shown in Figure 6, this is a statistical table of employee turnover after an enterprise optimizes the human resource allocation method. According to the trend of the chart and the previous theoretical methods, the optimization of the human resource allocation method by using a cyclic neural network algorithm can greatly reduce the turnover rate of employees and ensure the steady rise of enterprises.

5. Conclusions and Future Work

With the rapid development of computer technology, the deep neural network has attracted great attention in academia and industry and is widely used in image processing, engineering early warning, and so on. At present, deep learning has been adopted by recommendation system research, partly because of its ability to process sequential information. This paper mainly studies the depth recommendation model based on recurrent neural network, summarizes the existing depth recommendation models, and applies them to the allocation of human resources in enterprises. The essence of the human resource scheduling model is to analyze human resource data and calculate the matching degree between manpower and position. Afterwards, the personnel scheduling is carried out according to the matching degree score between the manpower and position, which can be potentially abstracted into a recommendation model in essence.

This paper improves the basic neural network; uses the combination of the cyclic neural network model, global model, and local model; takes the data characteristics after hierarchical operation of the model as the network output; and then realizes the data processing. By using the hierarchical model structure to build the network, we can finally realize the high-precision matching and recommendation of manpower and posts. Our future work will focus on applying the method proposed in this paper to the study of the personnel arrangement process in projects for cloud resource allocation [14, 17], considering that the working ability of personnel will directly affect the efficiency of project completion.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Research Article

Construction of Music Teaching Evaluation Model Based on Weighted Naïve Bayes

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Evaluation of music teaching is a highly subjective task often depending upon experts to assess both the technical and artistic characteristics of performance from the audio signal. This article explores the task of building computational models for evaluating music teaching using machine learning algorithms. As one of the widely used methods to build classifiers, the Naïve Bayes algorithm has become one of the most popular music teaching evaluation methods because of its strong prior knowledge, learning features, and high classification performance. In this article, we propose a music teaching evaluation model based on the weighted Naïve Bayes algorithm. Moreover, a weighted Bayesian classification incremental learning approach is employed to improve the efficiency of the music teaching evaluation system. Experimental results show that the algorithm proposed in this paper is superior to other algorithms in the context of music teaching evaluation.

1. Introduction

Recently, music has become an important part of education. With the reform and development of music education and the introduction of foreign advanced teaching methods, music education as an important part of quality education has been paid more and more attention [1]. Music teaching has shifted from focusing on skills to cultivating students' emotions, attitudes, and values. Music teaching evaluation has shifted from summative evaluation to formative evaluation, from partial evaluation to comprehensive evaluation, and from focusing on results to focusing on the process [2].

The task of developing and implementing an effective evaluation process for music education seems to be more abstract than producing evaluation methods in other areas of teaching. Traditional methods to the evaluation of music to date failed to prepare evaluators with comprehensive information required to make educational decisions about music teacher performance. For educational leaders to make valid decisions about music education in our schools, more precise and accurate evaluation models will be required about the effectiveness and nature of music teacher evaluation. Music performance evaluation (MPE) is the process of identification, assessment, and modeling the impact of music on the human listener [3]. The majority of the initial researches in MPE investigated symbolic data collected from musical instrument digital interface (MIDI) devices. Recently, attention has moved to the investigation of audio signals.

The concept of applying technology to evaluate music teaching education is old. An initial attempt to point out the importance of systematic assessment of music acts for enhancing learning was carried out by Seashore in the 1930s [4]. One of the initial works discovering the benefits of computer-aided evaluation techniques for music was accomplished by Allvin [5]. He described the application of pitch detection to analyze errors in musical presentation and provide a positive response to the learners. However, currently, the music signal is different from the original sound wave. The musical signal is sampled, multiple times per second, and converted by an analog-to-digital converter into a series of digital values. These values characterize the digital audio signal and are used to regenerate the music. This musical signal comprises numerous acoustic information and features. Usually, these audio features are extracted from the small segments of the audio signal and then combined into a more abstract feature vector [6].

Music teaching evaluation systems usually depend upon extracting prominent and standard audio features from voice signal and then applying machine learning algorithms to describe the value of the performance. Kosina [7], for example, extracted audio features from the 3 second segments of musical sounds and classified the features with a neural network classifier. Knight et al. [8] execrated a group of audio features and employed a support vector machine (SVM) classifier to classify the tonal characteristics of trumpet performances into “good” or “bad” labels. An evaluation system based on the identification of pitch interval for the assessment of singing voice was presented in [9]. Abeßer et al. used the features of sound pitch and intonation a music sound and instrumental performances to determine the rhythmic accuracy [10]. Luo et al. extracted the music spectral, timbral, and pitch-based features to predict mistakes of the violin players [11].

Features based on associated pitch contours were extracted by Bozkurt et al. to investigate vocal conservatory exam sounds and categorize them as “pass “or “fail” [12]. Han and Lee [13] used the mel-frequency cepstrum coefficients (MFCCs) as features to detect common musical mistakes. Wu and Lerch [14] utilized sparse coding to extract features for developing regression models for the evaluation of music performances. The models exhibited enhancement in performance compared to other models.

Despite the different feature sets and machine learning algorithms used by the above works, the basic idea that links them together is that they all are based on features and classification algorithms tuned for a specific task [15–18]. Motivated by the triumph of these music evaluation systems, the inspiration of this study is to discover the potential of machine learning in the form of Naïve Bayes classifier for the valuation of music performance. In this study, we employ an improved Naïve Bayes classifier (NBC) for the music teaching evaluation. The Naïve Bayes method has become greatly popular for building classifiers. This is because of the ability of NBC to acquire prior knowledge, the distinctive knowledge representation of NBC, and the accuracy of NBC. Although NBC is capable of extraordinary classification performance [19, 20], questions remain about their performance in multilabel classification.

The remaining sections of the paper are organized as follows. In Section 2, we provide an outline of the commonly known machine learning techniques. In Section 3, we present the proposed music teaching evaluation model. The results are given in Section 4, and finally, the proposed work is summarized in Section 5.

2. Overview of Classification Algorithms

Classification is an important problem in supervised learning. Its purpose is to summarize the unique audio features and find a model or accurate description for each class. The trained classification model is used to classify the features set in the dataset, and the class of the new data with unknown labels can be recognized through the trained model. The classification problem is mainly divided into two phases: learning and classification. In the learning phase, according to the known training dataset, we use the appropriate learning method to train a classifier. In the process of classification, new input instances are classified by the learned classifier.

In machine learning, the common classification algorithms are NB, SVM, KNN, decision tree (DT), and artificial neural network (ANN). Among them, the NB algorithm is a classification method built on the Bayesian theorem, which introduces the theory of feature condition independence, and the classification model is easy to understand. SVM is a linear classification model with the largest hyperplane defined in the feature space. KNN assumes that given a training dataset, the class of the instance has been determined. When classifying new test cases, KNN first judges the class label of the k-nearest neighbor training instance and then uses the majority voting method to predict the class. The DT model is a tree structure, which denotes the process of predicting data item examples based on features. The DT learning process usually comprises three steps: feature selection, tree generation, and decision tree pruning. ANN can effectively solve the problem of nonlinear comprehensive evaluation and reduce the influence of human factors on decision-making results. It can fully model any complex nonlinear relationship and model the nonlinear process without knowing the cause of the data.

Different machine learning algorithms exhibit different properties. The effect of classification is mostly related to the characteristics of data and application background. Table 1 provides a comparative analysis of several common classification algorithms.

Based on a given problem of music teaching evaluation, the different machine learning algorithms can be selected for music teaching evaluation. Taking a sequence of evaluation attributes as input data and an evaluation grade as a class label, a classification algorithm can give the most likely class label for the new evaluation attribute, namely, the evaluation result. To make sure the reliability of the evaluation results, it is indispensable to use the appropriate evaluation index to construct the classifier. Accuracy is an important index to evaluate the performance of a classifier, which is the ratio of correctly classified data samples to the total number of applied samples in a given dataset. Accuracy can be computed as follows:

$$\mathrm{Acc} = \frac{N_c}{N}, \tag{1}$$

where Acc is the accuracy rate, N_c is the number of correctly classified samples, and N shows the total number of total samples.

K-fold cross-validation is a key statistical assessment technique, mostly used to assess the performance of machine learning algorithms. In this study, 10-fold cross-validation was applied in addition to accuracy to gauge the performance of the proposed technique.

Table 1: Comparison and analysis of classification algorithms.

Algorithm	Advantage	Shortcoming
NB	Classification efficiency is stable and suitable for multiclassification tasks and incremental training and has the best performance when the correlation of feature attributes is small.	It cannot make a very accurate estimation of the class probability, and the time efficiency is low when there are many attributes or the correlation between attributes is large.
SVM	It uses less training set and can deal with high-dimensional sparse text data, which has a certain robustness.	It depends too much on the position of positive and negative examples around the classification surface, and the selection of kernel function lacks guidance. When there are many samples, the training speed is slow.
KNN	Without parameter estimation, it is easy to deal with the case of a large number of categories, and the method is simple and stable.	The sample size is large; the space complexity is high; the memory overhead is large; and the selection of K value also directly affects the performance of classification.
DT	The model has a tree structure, readability, and high classification speed.	It is easy to overfit and ignore the correlation between attributes.
BP network	It has the ability of self-adaptive, strong nonlinear mapping, and fault tolerance.	It has slow convergence, is easy to fall into local minimum, and has strong sample dependence.

3. Music Teaching Evaluation Recognition Model

3.1. Principle of Naïve Bayes Algorithm. In the classification process of NB, the Bayesian theorem is applied. During classification, the prior probability of each category is obtained by learning a large training set, and then compute the posterior probability of an item x. Finally, the item x is predicted as one of the categories with higher posterior probability. Suppose D is the training dataset, $T = \{T_1, T_2 \ldots, T_n\}$ is the set of attribute variables, and n is the total attributes. $C = \{C_1, C_2, \ldots, C_m\}$ is the set of class variables; K is the number of classes; then a training sample can be represented as $\{\{x_1, x_2, \ldots, x_n, C, \}; j \in m, C_j$. It means that the class label of the training sample is given, and a test sample x can be represented as the probability of $\{x_1, x_2, \ldots, x_n\}$ judging that the test sample is related to a certain class. This can be computed using the following equation:

$$p\left(C_j \mid X\right) = \arg\max_{C_j} \frac{p\left(X \mid C_j\right) p\left(C_j\right)}{p(X)}. \tag{2}$$

NB is an effective classification algorithm. The classification model has the advantages of simple explanation, high computational efficiency, and good stability, and its performance is superior to DT, SVM, and other classifiers in some cases. The Naïve Bayesian model adopts the simplest network structure, as shown in Figure 1.

The root node C is the class variable, and the leaf nodes $A_1, A_2, \ldots, A_n$ are the attribute variables. The NB classification depends upon the ordinary Bayesian theory, which avoids the condition that the attributes are independent. If $p(X)$ is a constant, then the NB model can be represented using the following equation:

$$p\left(C_j \mid X\right) = \arg\max_{C_j} p\left(X \mid C_j\right) p\left(C_j\right), \tag{3}$$

where $p(C_j)$ is a kind of prior probability that can be learned from training data as follows:

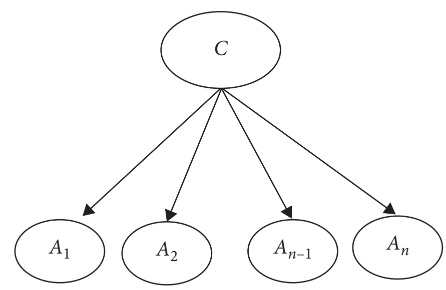

Figure 1: NB classification model.

$$p\left(C_j\right) = \frac{s_j}{s}, \tag{4}$$

where s_j is class in training samples C_j and s represents training samples.

NB algorithm assumes that all attribute variables are conditionally independent, and there is no relationship between attributes, so these attribute variables are also independent of the class attribute. The computation cost of $p(X \mid C_j)$ is very large, and the condition of independence can reduce the computation cost, but it will also lose some computational accuracy. Based on the conditional independence hypothesis, $p(X \mid C_j)$ the equation can be simplified as follows:

$$p\left(X \mid C_j\right) = \prod_{i=1}^{n} p\left(X \mid C_j\right), \tag{5}$$

where $p(x_1 \mid C_j), p(x_2 \mid C_j), \ldots, p(x_n \mid C_j)$ can be obtained from the training set. Combined with the above three equations, the class of test samples can be determined.

3.2. Determination of Weight Attributes Based on Weighted Naïve Bayes. To reduce the computational cost, in the NB algorithm, it is assumed that the condition attributes are independent of each other, and their importance in decision-making is the same for all attributes, that is, the weight is equal to 1. However, in practical application, the significance of each conditional attribute varies; therefore, when the default ownership weight is 1, the accuracy of classification is reduced. In this study, the weighted Naïve Bayes (WNB) algorithm is used to assign an appropriate weight to the attributes based on their contribution to classification. It retains the computation speed and also decreases the influence of the attribute conditional independence statement on the classifier performance. The weighted NB is computed as follows:

$$p(C_j \mid X) = \arg\max_{C_j} p(C_j) \prod_{i=1}^{n} p(A_i \mid C_j)^{wi}, \tag{6}$$

where w_i denotes the weight of attribute A_i. The weight governs the significance of various classification attributes. The higher the value of w_i is, the greater the corresponding attribute A will be. In many applications, the prediction of a precise weight for each attribute is the key problem of the WNB model.

Based on the correlation between the evaluation attributes of music teaching evaluation data and the comprehensive evaluation value, it can be observed that the value of each index has a distinct effect on the results of the evaluation. In this study, we propose a new method to define the weight of each evaluation attribute by calculating the correlation probability of attributes in class. Each attribute A_i may have n different values, where $n \in N$. Suppose a concrete instance z, when the value of z is a_k for a given class C_j, attribute a A_i about C_j the correlation probability and uncorrelated probability are calculated using Equations (7) and (8), respectively:

$$p(A_i \mid \text{rel}) = \frac{\text{count}(A_i = a_k \wedge C_j)}{\text{count}(A_i = a_k)}, \tag{7}$$

$$p(A_i \mid \text{norel}) = 1 - p(A_i \mid \text{rel}), \tag{8}$$

where count is the statistical number; when the value of A_i is a_k and belongs to C_j for class, the attribute weight can be computed using the following equation:

$$w(A_i, a_k, j) = \frac{p(A_i \mid \text{rel})}{p(A_i \mid \text{norel})}. \tag{9}$$

Hence, the equation of the WNB algorithm is as follows:

$$p(C_j \mid X) = \arg\max_{C_j} p(C_j) \prod_{i=1}^{n} p(A_i \mid C_j)^{w(A_i, a_k, j)}. \tag{10}$$

In a dataset, suppose there are l class labels, n attributes, and K attributes for each attribute, then the total number of weights for all attributes is $l * n * k$. Different values of the same attribute lead to different weights. When the value of the same attribute is the same, the weight is different under different categories. Finally, corresponding to each attribute value, the weight of the correlation probability with the present class label is used for computation, and the output of each class is compared. The class with the maximum value is the classification result. The specific steps of the WNB algorithm are given in Algorithm 1.

3.3. Incremental Learning of WNB Algorithm. In the WNB algorithm, the idea of incremental learning can reduce the performance requirements of the algorithm. The Bayesian classifier has a unique characteristic of incremental learning. A large part of the calculation process can be carried out in the way of incremental learning, which can reduce the time consumption of the algorithm. At the same time, the prediction performance of the classification algorithm is not affected by the completeness of training samples. Generally, the more complete the training samples are, the stronger their prediction ability and generalization ability are. In practice, the training samples of the classifier need to be gradually completed, and it is difficult to complete all the samples at one time. The incremental learning process of Bayes is to update the original class prior probability according to the new sample data $p(C_j)$ and attribute conditional probability $p(x_1 \mid C_j)$. The incremental learning of the algorithm is Algorithm 1:

The classifier does not need to retrain the classification model but only needs to import the newly added data into the classification model and modify the relevant parameters of the classifier. The modified equation of prior probability of Bayesian incremental algorithm is as follows:

$$P(C_j) = \begin{cases} \dfrac{N}{N+1} P(C_j) + \dfrac{N}{N+1}, & \text{when } c_t = c_j, \\[2ex] \dfrac{N}{N+1} P(C_j), & \text{when } c_t \neq c_j. \end{cases} \tag{11}$$

Likewise, the modified equation of the conditional probability of the Bayesian incremental algorithm is as follows:

$$P(C_j) = \begin{cases} \dfrac{N}{N+1} P(x_j \mid C_j) + \dfrac{N}{NC_j + 1}, & \text{when } c_t = c_j \text{ and } x_i = a_k, \\[2ex] P(x_j \mid C_j), & \text{when } c_t \neq c_j, \\[2ex] \dfrac{NC_j}{NC_j + 1} P(x_j \mid C_j), & \text{when } c_t = c_j \text{ and } x_i \neq a_k, \end{cases} \tag{12}$$

where $p(C_j)$ and $p(x_1 \mid C_j)$ are the class prior probability and attribute conditional probability updated after adding new samples, n is the total number of original data records, Nc_j is the total number of original data records means belonging to category C_j, and a_k is the value of a feature. In addition, when a new sample is added, it is necessary to count the number of samples of each category corresponding to the attribute value of the new sample set again. Combined with the statistical value of the old sample data, the correlation probability and noncorrelation probability value of the attribute are updated, to update the weight of each attribute. Using equations (9) and (10), and weighted

Input: test case to be classified
Step 1: scan all the training sample data and count the class label C. At the same time, the statistical attribute a, the number of samples whose value is AE, and the number of samples whose value is not a, are recorded in the count table.
Step 2: based on the information in the count table, for all attributes values, the correlation probability, and noncorrelation probability are calculated using equations (7) and (8), and the results are saved in the RP table.
Step 3: acquire the weight parameter. Using the information in the RP table, the weights of all attributes for various class labels are calculated using formula (9), and the weights are saved in the weight table.
Step 4: learn a priori probability. Using the number of classes in the count table, equation (4) is used to calculate the a priori probability of all class labels and save it to the correlation probability (CP) table. Meanwhile, equation (5) is used in the calculation of conditional probability for all attributes, and the results are saved in the conditional probability table (CPT) table.
Step 5: implement classification. When predicting the category of a test case, the CP table and the CPT table are called first, and then the corresponding value in the weight table is called using the specific value of each attribute. Finally, the posterior probability of the case belonging to each category is calculated using equation (10), and the maximum posterior probability is found out, and the class label is assigned.
Output class labels

Algorithm 1: Step of weighted Naïve Bayes classification.

Bayes equation (12), the category C_j of each data record x can be calculated.

4. Results

4.1. Comparative Analysis of Classification Accuracy of Traditional Machine Learning Algorithms and NB Algorithm. In this section, the five well-known machine learning classification algorithms are used to evaluate the existing teaching evaluation dataset, and the feasibility of the algorithm is judged by its accuracy. For each classification algorithm, we used the algorithm function provided by Sklearn, a machine learning library of the Python language. The default parameters were used to compare the experimental results. The dataset was divided into 220 training sets and 70 test sets. We applied 10-fold cross-validation in which the dataset was categorized into 10 equal parts. At each iteration, 1 part was used for testing, and the remaining 9 parts were used for training the classifier. The final results were averages as shown in Table 2.

The average classification results of these classification algorithms are shown in Figure 2.

For the same experimental dataset, the average computation time of each algorithm is shown in Table 3.

NB algorithm has high classification accuracy and the minimum running time on the dataset. The highest average computation time of 34.9 s was taken by the BP algorithm, whereas the NB algorithm took only 0.06 s to complete the classification task. Therefore, this validates the selection of the NB algorithm as the best candidate machine learning algorithm for the construction of the music teaching evaluation model.

4.2. Comparative Analysis of Classification Accuracy of NB and WNB Algorithms. We compared the performance of standard NB and WNB classifiers based on classification accuracy and competition time. All the 290 music samples were divided into 10 equal parts with 220 samples used for training and 70 samples for testing the classification performance. Using 10-fold cross-validation, the classification performance of the NB and WNB algorithms was measured. The results are given in Table 4.

The experimental results show that the average accuracy of the NB algorithm is 0.71%, whereas the average accuracy of the WNB is 0.75%. It can be observed that the classification accuracy of the WNB algorithm is better than that of the traditional NB algorithm in the music teaching evaluation dataset.

Since neural networks have rapidly gained attraction within the music fields [21] Among the different classes of the neural network, the backpropagation (BP) neural network is probably the most widely used. When the BP neural network algorithm processes the training dataset, it unifies the original score value (percentage system) into a decimal of the [0, 1] interval through data normalization and sets an error threshold to form a model to identify the evaluation level of the new sample data. We experimented with the BP algorithm, where all the 220 music samples were arbitrarily chosen as the training set and 70 data samples as the test set. According to the number of attributes, the input layer node was set to 10; the hidden layer node was 5; the output layer node was 1, the activation function was tanh(); the learning rate was 0.01; and the number of cycles was 10,000. After the neural network algorithm training, the test results are shown in Table 5.

Based on the above analysis, since in the actual evaluation process, the percentage system evaluation value given is generally very high, which leads to model overfitting, resulting in a high prediction level. Therefore, after preprocessing, the percentage score value was discretized into the evaluation value of the five grade system, and the data of different grades were randomly selected and mixed into the training dataset, in which the training set contained 220 and the test set contained 70 data samples. The results of the BP network and WNB algorithm were computed and are shown in Table 6 and Figure 3.

According to Table 6, the comparison chart of classification accuracy between the NB and WNB algorithms is shown in Figure 3.

Table 2: Record of classification accuracy.

	10-fold cross-validation										
Algorithm	1	2	3	4	5	6	7	8	9	10	Average
NB	0.8	0.757	0.8	0.743	0.757	0.8	0.757	0.729	0.729	0.771	0.764
SVM	0.671	0.586	0.671	0.757	0.757	0.7	0.7	0.657	0.743	0.714	0.695
KNN	0.686	0.757	0.671	0.743	0.671	0.686	0.686	0.671	0.743	0.686	0.7
DT	0.65	0.628	0.686	0.7	0.642	0.717	0.7	0.657	0.7	0.657	0.674
BP	0.771	0.728	0.714	0.814	0.7	0.714	0.7	0.628	0.729	0.729	0.723

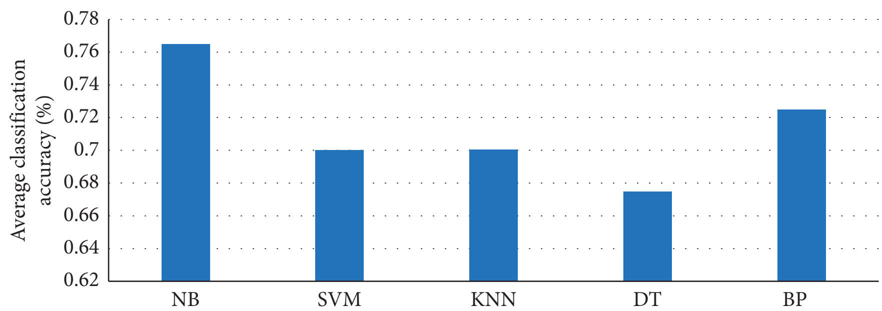

Figure 2: Classification accuracy of common algorithms.

Table 3: Average computation time (s).

Algorithm	NB	SVM	KNN	DT	BP
Average time consumption	0.068	28.961	3.353	0.131	34.908

Table 4: Classification accuracy of NB algorithm and WNB algorithm.

	10-fold cross-validation										
Algorithm	1	2	3	4	5	6	7	8	9	10	Average
NB	0.729	0.700	0.714	0.671	0.700	0.714	0.729	0.757	0.729	0.686	0.713
WNB	0.700	0.757	0.771	0.729	0.786	0.729	0.843	0.743	0.700	0.729	0.750

In the actual teaching evaluation dataset, because there are more excellent grades in the evaluation grade and fewer other grades when using hierarchical data to train the classification model when the extracted training datasets are different, the experimental results will be affected to a great extent. In this experiment, the average accuracy of the WNB algorithm is 0.767, and that of the BP algorithm is 0.683. The experimental results show that the performance of WNB is better than that of the BP algorithm. Likewise, the average computation time of WNB is 0.025 s, while the average computation time of the BP algorithm is about 34 s. Compared with the BP algorithm, the time consumption of the WNB algorithm is less, and the recognition accuracy is higher. Hence, the WNB algorithm has greater advantages in music teaching evaluation.

4.3. Experimental Analysis of WNB with Incremental Learning-Based WNB. We completed the construction of an incremental classification model based on WNB with 220 training samples and 70 test samples and gradually increased the training sample sets. The specific calculation results of test samples in each phase of random sampling increment are shown in Table 7.

Using incremental learning strategy, the calculation results are more inclined to the correct category, that is, the probability value of the correct category increases, while the probability value of other categories decreases. With incremental strategy, the changes of average classification accuracy are shown in Table 8, which shows a very small degradation in performance while adding more samples.

WNB algorithm with incremental learning referred to as adding WNB algorithm; using the same experimental dataset, the consumption time of WNB with incremental strategy is shown in Figure 4.

The introduction of the incremental model not only helps improve the classification model. At the same time, because the incremental model does not need to train and calculate the previously trained dataset again, it only needs to classify and calculate the newly added data, directly merge with the previous training values, and update the relevant parameters of the model, which saves time and increase the

Table 5: Some experimental results of the BP algorithm.

True evaluation value	Rank value	Predicted calculated value	Error range	Forecast level
0.98863	Excellent	0.927	0.060	Excellent
0.94318	Excellent	0.908	0.034	Excellent
1	Excellent	0.928	0.071	Excellent
0.97727	Excellent	0.946	0.031	Excellent
0.98863	Excellent	0.953	0.034	Excellent
0.96591	Excellent	0.924	0.041	Excellent
1	Excellent	0.918	0.081	Excellent
0.88636	Good	0.927	−0.041	Excellent
0.54545	Unqualified	0.819	−0.274	Good
0	Unqualified	0.291	−0.291	Unqualified

Table 6: Classification accuracy of BP and WNB algorithms.

Frequency	1	2	3	4	5	6	7	8	9	10	Average
BP	0.743	0.657	0.671	0.629	0.771	0.657	0.7	0.729	0.643	0.629	0.683
WNB	0.729	0.786	0.814	0.729	0.757	0.771	0.729	0.843	0.729	0.786	0.767

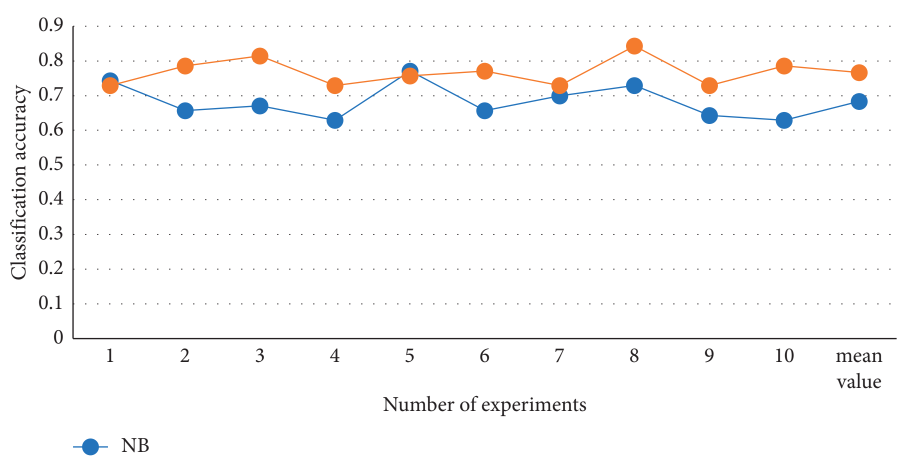

Figure 3: Comparison of classification accuracy of BP and WNB algorithms.

Table 7: Calculation results of test data.

Number of increments	50 more		Add 100		150 more		Add 180	
	Before increment	After increment	Before increment	After increment	Before increment	After increment	Before increment	After increment
Grade	Excellent		Excellent		Good		Good	
Excellent	$1.1e-09$	$2.5e-09$	$3.9e-08$	$2.1e-08$	$3.5e-06$	$2.9e-06$	$1.3e-05$	$1.2e-05$
Good	$1.5e-12$	$5.6e-15$	$7.2e-14$	$5.le-13$	$2.9e-06$	$7.4e-06$	$1.9e-08$	$4.1-08$
Secondary	0.0	0.0	0.0	0.0	$3.0e-05$	$7.3e-06$	0.0	0.0
Qualified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unqualified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Judgment result	Excellent	Excellent	Excellent	Excellent	Secondary	Good	Excellent	Excellent

Table 8: Classification accuracy before and after the increment.

Increment value	Before increment	Add 50	Add 100	Add 150	Add 180
Average accuracy	0.721	0.732	0.724	0.731	0.751

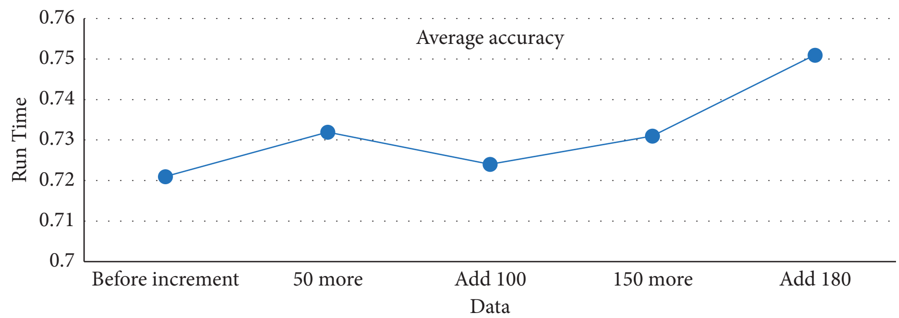

Figure 4: Algorithm running time comparison.

effectiveness of the classification model. Although the results of the proposed model are encouraging, more work is required to test the performance on other musical datasets and advanced machine learning algorithms.

5. Conclusion

This article explores the construction of a music teaching evaluation model using machine learning techniques. By comparing the potential of traditional classification algorithms, the weighted Naïve Bayes algorithm is presented as the baseline algorithm for the music teaching evaluation process to evaluate the music teaching effect. In addition, the concept of incremental learning is introduced to improve the classification performance of the weighted Naïve Bayes classifier. The experimental results show that the introduction of the incremental learning approach not only optimizes the performance of the classifier but also reduces the computation time of the algorithm. Results validate that the algorithm proposed in this paper is superior to other algorithms in the performance of music teaching evaluation.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Prediction and Evaluation Model of Physical Training for Volleyball Players' Effect Based on Grey Markov Theory

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Physical competition is becoming the new focus of volleyball in an increasingly perfect technical and tactical system. Unfortunately, poor physical fitness is a recognized weakness of volleyball players and a critical factor that has restricted the rapid development of volleyball for a long time. This paper proposes a grey Markov model-based approach to improve the evaluation ability of physical training. It aims to construct an empirical analysis model by combining statistical results and analyzing the evaluation parameters for physical training effects. The sports parameter analysis method is adopted to establish an optimal model of these parameters. Finally, a distribution model of moments of inertia combined with fuzzy information fusion's feature extraction method is proposed for the distributed reconstruction of physical training. The optimization of training effects based on parameter optimization and construction of a grey Markov model enhances the physical training of volleyball players.

1. Introduction

Due to the socialization and commercialization of competitive sports, more and more countries have begun to invest a lot of manpower and material resources to develop their competitive sports, resulting in increasingly fierce competition in the world sports arena. At present, action technology has reached a relatively mature level. In various competitions, the tactical system composed of multiple action techniques has also been flourished. The publication of different teaching materials and monographs, the current timely reports of various media, and the dissemination of information on the Internet and their respective skills and tactics are not a secret. Therefore, physical fitness has become a particularly prominent factor in winning in sports competitions and achieving excellent sports performance. It can be seen from the competitions of various sports that the situation of relying solely on technical and tactical advantages to win the game is no longer comparable to the past [1–4]. Athletes or teams with superior skills and tactics cannot win the final competition, often due to physical fitness, the shortcomings, especially when the level is exceptionally high. Although volleyball belongs to the skill-led competition of the net, it is also facing this situation. With more and more countries paying attention to volleyball, the current volleyball game has broken the original monopoly, showing a more intense situation of solid competition. With the rapid development of the world volleyball technical level and the continuous modification and improvement of competition rules, modern volleyball technology develops towards higher serve points, diversified cushioning, passing speed, spiking power, and blocking cavitation. Especially, in recent years, its development momentum has become even fiercer [5–8]. This development trend of modern volleyball technology has increasingly made physical fitness a critical factor in winning.

For a volleyball team to achieve excellent sports performance, it must achieve a highly coordinated development of physical fitness, intelligence, tactics, technology, and psychology, as shown in Figure 1. Among the five competitive ability elements, physical fitness is the foundation as good physical fitness will provide the premise and possibility for the full use of skills and tactics [9–14]. Physical fitness is closely related to the application effects of skills and tactics. Today, with the increasingly complete technical and tactical system, physical fitness competition is becoming the new

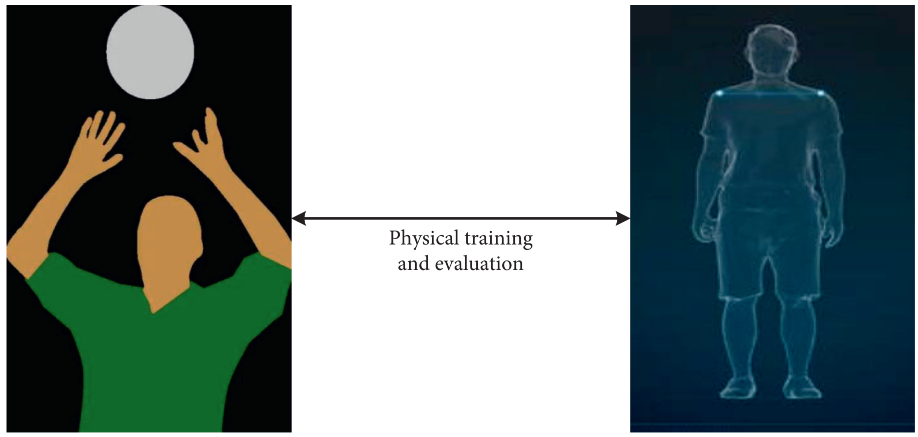

Figure 1: Volleyball and physical fitness assessment.

focus of volleyball competitions. Modern volleyball is developing in the direction of fast-paced and intense confrontation, and this fast-paced and strong confrontation requires good physical fitness as a guarantee. Therefore, strengthening the special physical training and improving the athletes' special strength level, jumping ability, and fast movement ability will positively affect the application of skills and tactics in the competition.

With the continuous development of intelligent sports training technology, intelligent digital analysis and quantitative analysis methods are used to evaluate athletes' physical training effects. This approach is combined with parameter optimization and big data analysis techniques to build a big data analysis model for assessing athletes' physical training effects [15–19]. Furthermore, the proposed approach is combined with information fusion to improve the accuracy of evaluation and study various models of athletes' physical training effects, which is of great significance in promoting the optimization of their training [20–25]. We combine the grey theory and Markov theory to formulate a grey Markov physical training effect prediction and evaluation model for volleyball players. This combination can reveal the general trend of physical training of these players. Our model has the ability to reflect the development trend of the data sequence and can also reduce the range of prediction interval via the transformation of state transition probability matrix. Hence, the prediction is more adaptable and the accuracy is much higher.

The rest of this paper is organized as follows. In Section 2, the related work is presented. In Section 3, the proposed prediction and evaluation model of physical training effect is discussed. In Section 4, the model is tested and discussion of experimental results is provided. Finally, the paper is concluded and future research directions are provided in Section 5.

2. Related Work

The evaluation standard is the scale that measures the evaluation objects to meet the requirements of any evaluation index. Therefore, the establishment of scientific and reasonable evaluation standards is of great significance for improving the quality of evaluation. At present, the relevant data related to the volleyball physical fitness evaluation model and standard are summarized as follows. Fu and Cheng [26] put forward the concept of volleyball index, which is used to measure the relationship between the height of volleyball players, the height of the jump, and the height of net in the training competition. Wang [27] conducted an efficient comprehensive multi-index evaluation of the physical fitness of Chinese juvenile volleyball players. Using the percentile system and the average $\pm$ 4 times the standard deviation, they formulated 13 individual scoring standards for physical fitness, and two comprehensive evaluation regression equations are established using the stepwise regression method. Chen [28] established a mathematical model that distinguishes the physical fitness of volleyball players. The 100-meter run that affects the physical fitness is followed by five-level leapfrogging, approach run, 800-meter run, sloping abdomen, and 6-meter run. Yang [29] reprinted the American Men's Volleyball players' Physical Fitness Test Evaluation Form, which included a total of 16 evaluation indicators such as height, single finger height, vertical jump, and block jump, using a 30-point system. Zhang et al. [30] used the progressive scoring method to determine the six physical fitness features of volleyball players, i.e., walk-up touch, 100-meter run, five-level leapfrogging, sloping abdomen, weight-bearing back muscles, and 6-meter movement. It also uses the deviation method to establish the individual and comprehensive physical fitness evaluation standards of athletes (excellent, good, medium, passing, and poor five-level evaluation form). Feng and Mei [31] established the physical fitness evaluation model of different groups of athletes based on special physical fitness of juvenile volleyball players. Yang et al. [32] and Tang et al. [33] established the 100-meter run, 60-meter run, 800-meter run, 1500-meter run, 36-meter movement, the approach height, and the supine abdomen, among others. The physical fitness test evaluation standard conducted by the Chinese Volleyball League also adopts the 100-point system.

In training, coaches and scientific research assistants must pay attention to obtain various feedback information about athletes training, so as to better control the whole training process and make training more systematic. Obtaining training information is accomplished through monitoring measures, and then, the acquired information is processed to obtain valuable reference materials to guide future training practices. This processing is essentially the standard procedure for diagnosis. Due to the long-term nature of the physical training process and the complexity of influencing factors, coaches and scientific researchers are required to continuously monitor and evaluate the athlete's training status and make timely adjustments to the training content and methods. With the rapid development of modern science and technology, the methods of training and monitoring have become more advanced and the effects have become more and more obvious. As a result, many countries have established "comprehensive monitoring systems for advanced athletes" for some key projects, so as to achieve effective control on the basis of systematic procedures and have achieved good results. For example, Italy, the Netherlands, Germany, and other European countries use advanced computer technology to quantitatively monitor the physical training process, especially the quantitative evaluation and control of training load, which makes the regulation of the physical training process more scientific. To date, the data on monitoring and diagnostic evaluation of physical training for volleyball has not yet been seen, but there have been beneficial attempts in physical training for other sports in China. Jiang and Chen [34] developed a monitoring and analysis system for an efficient athlete' physical fitness and skills, which has four main functions: data entry and performance conversion, vertical and horizontal analysis, result output, and decision-making plans. In this article, the author puts forward three suggestions for further improvement of the system in the future: increase horizontal comparative analysis, increase intelligent functions, and increase comprehensive evaluation functions.

3. Prediction and Evaluation Model of Physical Training Effect

We utilize grey Markov theory to construct a prediction and evaluation model of physical training effect for volleyball players. The architecture is illustrated in Figure 2.

This section is organized as follows. In Section 3.1, the theoretical basis for predicting and evaluating the physical training is discussed. In Section 3.2, the information sampling and feature analysis of training effect is discussed. Finally, in Section 3.3, prediction and the construction of evaluation model is discussed.

3.1. Theoretical Basis. Both grey theory and Markov theory can be used for the prediction and evaluation of time-series problems. The advantage of grey theory lies in short-term forecasting, but its disadvantage is the poor fitting of long-term forecasts and large volatility data series. The advantage of Markov theory lies in long-term prediction of data series with large random volatility, which can just make up for the limitations of grey theory. However, the prediction of Markov theory is required not only to have the characteristics of Markov chain but also to have the characteristics of the mean value of the stable process. Most of the physical training activities are nonstationary random processes that show a certain trend of change over time. The mechanism of Markov chain is shown in Figure 3.

By combining the grey theory and Markov theory, we can formulate a grey Markov physical training effect prediction and evaluation model that can reveal the general trend of physical training and development. The newly built model not only reflects the development trend of the data sequence but also reduces the range of prediction interval via the transformation of state transition probability matrix. Therefore, the prediction is more adaptable and the prediction accuracy is higher.

3.2. Information Sampling and Feature Analysis of Physical Training Effect. In order to realize the optimization design of the athlete's physical training effect evaluation model based on the Markov model, the big data feature analysis method is used to carry out the adaptive optimization of the their training effects. In doing so, the adaptive fusion parameter analysis model for the evaluation of the athlete's physical training effect is established. The method of data analysis and feature scheduling is used to sample the big data information of the athlete's training effect and evaluation, combined with the statistical information mining method to evaluate the effect of their physical training [35]. It can be formulated as follows:

$$X^{(0)} = \bigcup_{i=1}^{N} x^{(i)}. \tag{1}$$

The similarity feature's analysis method is used to carry out statistical analysis and optimization evaluation of the athletes' physical training effect and evaluation. The multiple regression test analysis method is adopted to establish the fuzzy constraint parameter analysis model of their training effects. The fuzzy statistical analysis and quantitative game method are used to carry out the athletes' physical training. The adaptive learning of the evaluation, the establishment of a quantitative analysis model for the evaluation of athlete's physical training, and the statistical function for the evaluation of the athlete's physical training effect is calculated as follows:

$$\begin{gathered} \min F = R^2 + A \sum_i \xi_i, \\ \left\| \varphi\left(x_i\right) - o \right\|^2 \leq R^2 + \xi_i. \end{gathered} \tag{2}$$

This equation aims to combine the autocorrelation feature matching method for the fusion processing of athletes' physical training and improve the adaptability of evaluating their training effects.

Next, the statistical analysis of mechanical parameters and the method of big data sampling are combined, and big data fusion processing of these parameters is carried out. The descriptive statistical sequence of the athlete's physical training effect is depicted and formulated as follows:

Figure 2: The overall architecture of our prediction and evaluation model.

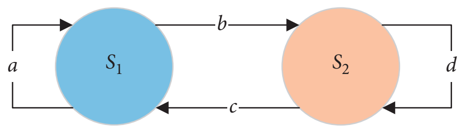

Figure 3: The mechanism of Markov chain.

$$x_i = x\left(t_0 + i\nabla t\right), \quad i = 0, 1, \ldots, N-1. \tag{3}$$

The quantified set of optimized feature parameters for athletes' physical training is

$$X = \left[s_1, s_2, \ldots, s_k\right]_n. \tag{4}$$

Next, an evaluation model of athlete's physical training effect based on the joint analysis of physical endurance and explosive power characteristics is designed and combined with statistical data and big data sampling methods to analyze the evaluation parameters of athletes' physical training and a fuzzy parameter fusion model for the evaluation is established. The expression of the statistical analysis model for constructing the evaluation of the physical fitness training effect of big athletes is

$$\frac{\mathrm{d}z(t)}{\mathrm{d}t} = F(t). \tag{5}$$

We use mechanics sensors to collect explosive physical data of athletes' physical training by designing a parameter distribution model and performing associated scheduling and ambiguity feature analysis. A distribution model of inertial moments of athletes' physical training explosives is designed and combined with fuzzy information fusion feature extraction to perform distributed reconstruction of the mechanical characteristics of athletes' physical training. The distribution of mechanical characteristics of athletes' physical training is as follows:

$$\lambda = \frac{1}{\left(1 + \alpha\left(\partial s/\partial t\right)^2\right)}. \tag{6}$$

3.3. Physical Training Effect Prediction and Evaluation Model Construction. To understand the future grey prediction through processing of original data sequence and the establishment, learning, discovery, and mastering of the grey model, we make a scientific and quantitative prediction of the future state of the system. It is mainly used to fit and predict the eigenvalues of a dominant factor in a complex system, to reveal the changing law and the future development trend.

For data sequence test before grey model prediction, it is necessary to perform a grade comparison test on the original data sequence. The grade ratio test is formulated using

$$\alpha(k) = \frac{x^{(0)}(k-1)}{x^{(0)}(k)}, \quad k \geq 2. \tag{7}$$

If $\alpha(k) \in (e^{-(2/(n+1))}, e^{2/(n+1)})$, it is considered that the data sequence can be used to model and predict grey. In case of athletes, if any athlete does not meet this condition, then certain processing needs to be performed on the original data sequence to meet the conditions of grade ratio test. For this purpose, the data transformation is usually used. There are translation exchange methods, logarithmic transformation method, and square root transformation method, as well for this purpose. Next, we accumulate the original time data series as follows:

$$X_{(t)}^{(1)} = \left(x^{(1)}(1), x^{(1)}(2), \ldots, x^{(1)}(n)\right). \tag{8}$$

Generate sequence $X_{(t)}^{(1)}$ with equal weights adjacent to $Z_{(t)}^{(1)}$ as follows:

$$\begin{aligned} Z_{(t)}^{(1)} &= \left(z^{(1)}(1), z^{(1)}(2), \ldots, z^{(1)}(n)\right), \\ z^{(1)}(1) &= x^{(1)}(1), \quad k = 1, \\ z^{(1)}(k) &= 0.5x^{(1)}(k) + 0.5x^{(1)}(k-1), \quad k > 1. \end{aligned} \tag{9}$$

The first-order univariate differential equation is used to fit and model the generated data sequence, and the grey prediction model is obtained as follows:

$$\frac{\mathrm{d}x^{(1)}}{\mathrm{d}t} as + ax^{(1)} = b, \tag{10}$$

where a is the development parameter and b is the grey effect.

Please note that the parameter column $\overline{a} = (a, b)^T$ is determined using the least square method:

$$\begin{aligned} \widehat{a} &= \left(B^T B\right)^{-1} B^T Y_n, \\ B &= \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \cdots & \cdots \\ -z^{(1)}(n) & 1 \end{bmatrix}, \\ Y_n &= \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \cdots \\ x^{(0)}(n) \end{bmatrix}. \end{aligned} \tag{11}$$

Next, we find the solution of the whitening equation, that is, the time response sequence using

$$\overline{x}^{(1)}(k+1)=\left(x^{(0)}(1)-\frac{a}{b}\right)e^{-ak}+\frac{b}{a}. \quad (12)$$

To restore the value data sequence by accumulative subtraction generation method, we use

$$\overline{x}^{(0)}=\left(\overline{x}^{(0)}(1),\overline{x}^{(0)}(2),\ldots,\overline{x}^{(0)}(n)\right). \quad (13)$$

The Markov process is based on the state of each data in the existing data sequence and the state transition law constructed by the data sequence, predicting that a certain data system may appear in a certain state within a period of time in the future. To provide theoretical support for related decision management, the basic model of the Markov forecasting method is used as shown in

$$x(k+1)=x(k)\times P. \quad (14)$$

The change process of physical fitness is an unstable random process that randomly presents an upward or downward trend. The physical fitness data sequence conforms to the n-order Markov nonstationary random sequence. Take $\widehat{Y}(k)=\widehat{x}^{(0)}(k+1)$ as the baseline; according to the actual prediction of the physical fitness value, the physical fitness prediction sequence can be divided into several interval values, i.e., several states, as shown in equations (15)–(18):

$$Q_{1i}=[Q_{1i},Q_{2i}], \quad (15)$$

$$Q_{1i}=\widehat{Y}(k)+A_i, \quad (16)$$

$$Q_{2i}=\widehat{Y}(k)+B_i. \quad (17)$$

The number of original data samples from state Q_i to state Q_j after n-step transition is denoted as $M_{ij}^{(n)}$, where M_i is the frequency of state Q_i; then, the probability that a state reaches state Q_j after n-step transition is

$$P_{ij}^{(n)}=\frac{M_{ij}^{(n)}}{M_i}. \quad (18)$$

The state transition probability matrix is obtained using

$$P_{ij}^{(n)}=\begin{bmatrix} P_{11}^n & P_{12}^n & \ldots & P_{1n}^n \\ P_{21}^n & P_{22}^n & \ldots & P_{2n}^n \\ & & \ldots & \\ P_{n1}^n & P_{n2}^n & \ldots & P_{nn}^n \end{bmatrix}. \quad (19)$$

Through the obtained one-step state transition probability matrix, the current initial state distribution can be determined, and the state or development trend that may appear in the future can be predicted. The state transition probability matrix reflects the transition law between various states in the system. Moreover, it can determine the turn of the future state.

When the future direction of the system is determined, the change range of its grey function is determined as $[Q_{1i},Q_{2i}]$. Since Q_{1i} and Q_{2i} are the lower critical value and upper critical value of a certain state area, respectively, the interval average value is taken as the predicted value in the future. The calculation formula is

$$Y'(k)=0.5\left(Q_{1i}+Q_{2i}\right). \quad (20)$$

According to equations (16) and (17), equation (20) can be transformed as follows:

$$Y'(k)=\widehat{Y}(k)+0.5\left(A_i+B_i\right). \quad (21)$$

To further improve the accuracy of the model, in future predictive modeling, this article first uses the metabolic method in the grey theory model to process the original data and then performs grey Markov modeling and prediction. In the modeling process, the data sequence is divided into many states, and the middle value of the grey element interval is taken as the final prediction value to achieve higher prediction accuracy. If the state of the division is small, a relatively conservative prediction principle can be used, and the grey element interval can be adopted. The lower value of the critical value is used as the predicted value.

4. Model Testing and Discussion

It is impossible for any prediction model to be 100% accurate. Hence, whether the prediction of the grey Markov model is reliable requires a quantitative test for accuracy. This article not only uses residual test and posterior test but also uses the grey system theory analysis method, and model testing, testing the relevance of the original data series and the predicted data series. The classification of accuracy testing is detailed in Table 1:

To verify the performance of the proposed method for the realization of athletes' physical training effects, simulation test analysis was carried out. SPSS 14.0 statistical analysis software was used to analyze the constraint parameters of athletes' physical training effects and statistical analysis, and mechanical sensors were used to evaluate the effects of athletes' physical training. The statistical analysis results of physical information collection and physical training effect are shown in Table 2.

According to the data of Table 2, the development parameters and the grey effect are obtained, and then, they are substituted into the definition of grey prediction. A model is obtained for predicting values and residuals of the first five volleyball athletes' physical training performance, as shown in Table 3.

It can be seen from the experimental results that the prediction error is small and within an acceptable range, which shows the validity of the model. Since the fifth prediction is not the optimal state, the actual value is used as the initial state, and the seventh physical fitness prediction and correction is carried out. It is found out that the sixth prediction effect is better. The comparison result with GM is shown in Table 4. In this table, "AV" is the actual value, "PV" is the predictive value, "RR" is the relative residual, and "RV" is the revised value.

It can be seen from Table 4 that the accuracy of the GM (1, 1) model is significantly improved after the grey-scale Markov chain is corrected, and the relative error is reduced.

Table 1: Accuracy inspection: grade reference table.

Accuracy level	Residuals	Relative residuals
Excellent	0.35	0.01
Good	0.50	0.05
Qualified	0.65	0.10
Unqualified	0.80	0.20

Table 2: Statistical analysis for evaluating physical fitness training effect.

Variable	Mean	Standard value	Minimum	Statistical average
Exercise time	0.265	0.675	0.136	5.701
Physical fitness	0.363	0.534	0.355	2.455
Daily exercise	0.549	0.422	0.451	2.565
Training intensity	0.450	0.470	0.373	4.536
Correlation coefficient	0.437	0.538	0.429	3.612

Table 3: Comparison of actual and predicted values of first five physical training.

Order	Actual value	Predictive value	Residual	Relative residual (%)
1	25.7	25.7	0	0
2	24.9	24.6	0.2	0.803
3	25.7	25.9	−0.2	−0.778
4	23.6	23.3	0.3	1.271
5	23.9	23.2	0.7	2.929

Table 4: The sixth training performance prediction value and correction value.

Order	AV	GM (1, 1)			Grey Markov model		
		PV	*R*	RR (%)	RV	*R*	RR (%)
7	24.8	24.1	0.7	2.823	24.5	0.3	1.210

The grey prediction model alone has a higher relative error. It can be seen that the accuracy of the grey Markov prediction model is obviously higher than that of the grey prediction model GM (1, 1) alone.

According to the descriptive statistical analysis results of the evaluation of athlete's physical training effect in Table 2, the evaluation of the physical training effect is carried out, and the collected results of the mechanical parameters of the athlete's physical training is obtained. Using the results of collected mechanical parameters of athlete's physical training in Table 2, we can evaluate the effect of athlete's physical training. The optimized output of the evaluation is shown in Figure 4.

Analyzing Figure 4, we know that the method in this paper has high accuracy in evaluating athletes' physical training effects, better feature tracking performance, and confidence in test evaluation. Compared with some similar methods [36] and [37], the comparison result is shown in Figure 5.

It can be seen that the model we proposed has strong competitiveness in terms of physical fitness prediction and assessment.

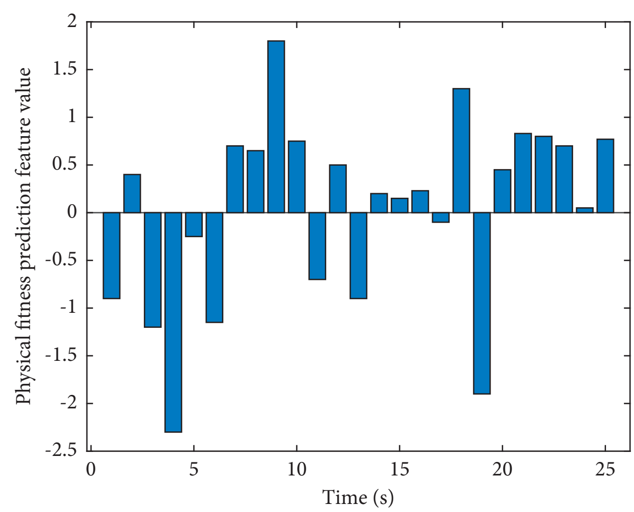

Figure 4: Athlete's physical training effect evaluation output.

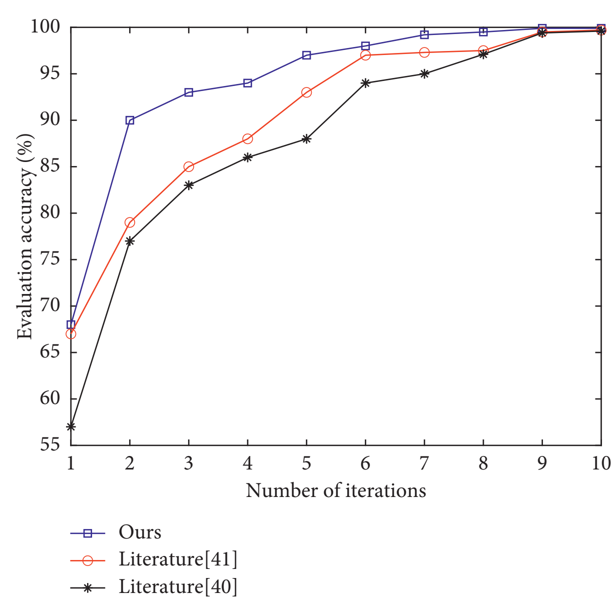

Figure 5: Evaluation accuracy comparison test.

5. Conclusions

In this paper, the grey Markov model is used to predict and evaluate the physical fitness changes of volleyball players. Initially, the players' training performance in each state is evaluated using the Markov model. The statistical results and evaluation parameters are combined to form an empirical model for training. The calculation of the model is relatively simple and the accuracy is much higher. The grey prediction model is mainly suitable for system objects with short prediction time and little fluctuation. Due to its own shortcomings, the proposed work can only be applied to systems where the original data sequence changes exponentially. The Markov model is suitable for predicting dynamic processes with large random fluctuations. At this point, it can make up for the shortcomings of grey prediction model to achieve complementary functions, highlight advantages, and improve the prediction accuracy. In the future, I aim to work on different models (other than Markov) for the prediction and evaluation of physical training of volleyball players to see the effects and efficiency.

Data Availability

The datasets used are available from the author upon reasonable request.

Conflicts of Interest

The author declares that he has no conflicts of interest.

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Research Article

Eye Movement Prediction Based on Adaptive BP Neural Network

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This paper uses adaptive BP neural networks to conduct an in-depth examination of eye movements during reading and to predict reading effects. An important component for the implementation of visual tracking systems is the correct detection of eye movement using the actual data or real-world datasets. We propose the identification of three typical types of eye movements, namely, gaze, leap, and smooth navigation, using an adaptive BP neural network-based recognition algorithm for eye movement. This study assesses the BP neural network algorithm using the eye movement tracking sensors. For the experimental environment, four types of eye movement signals were acquired from 10 subjects to perform preliminary processing of the acquired signals. The experimental results demonstrate that the recognition rate of the algorithm provided in this paper can reach up to 97%, which is superior to the commonly used CNN algorithm.

1. Introduction

With the rapid advancement of artificial intelligence, individuals began to utilize machines to detect users' emotional states, and the machines were required to provide feedback based on human emotions, a mechanism known as the human-computer interaction. Detecting eye movement is an important research topic that has gained significant interest in recent years. Electrical impulses generated around the eyes by eye movements are known as oculomotor nerve signals [1]. Physically disabled people and the elderly with limited mobility may not be able to express their wishes through their bodies but can now use their eyes for emotional communication. Hence, if we can extract useful signals from each other's eyes and design a human-computer interaction system, we can assist human beings in realising the good wishes of human-computer [2]. Eye movement signals have the benefits of large amplitude, easy waveform identification, and easy processing when compared to other bioelectric signals, providing more reliable and convenient circumstances for collecting eye movement information [3]. This work focuses on how to gather eye movement data, as well as extracting, classifying, and identifying that data [4]. Compared with other methods, this paper proposes an adaptive BP algorithm, which mainly solves the problem of different lengths of eye movement information and substantially improves the recognition rate of eye movement signals, laying a good foundation for future human-computer interaction systems [5].

This study focuses on a combination of single and multiframe human eye tracking enhanced algorithms with radial blurring. The shading component, optimization, and characteristics of the radial rendering methodology are explored, the comparison with classic blurring effects is made, and the combination of single and multiframe human eye tracking improved algorithm with radial blurring is studied. The shading component, optimization, and characteristics of the radial rendering technique are explored, as well as the comparison with standard blurring effects and the integration of single and multiframe human eye tracking enhanced algorithms with radial blurring. Traditional blurring and Unity3D [6] are used to compare the outcomes with our work. Unity3D is used to demonstrate and deploy a combination of improved single and multiframe human eye tracking techniques with radial blurring. During eye tracking research, deep learning-based eye tracking techniques are also an important study direction. Human eye tracking is divided into single-frame image identification tasks and video frame tracking tasks by deep learning. Researchers have introduced numerous unique algorithms through research on human eye tracking [7], despite the fact that there are still challenges in deep learning-based human eye tracking. The proposed algorithms may be able to forecast position information when the eyes are obstructed.

The radial blurred scene rendering function based on human eye tracking is proposed in the virtual reality scene to improve the user's immersion, with the user immersion index equal to the scene (fps reaching 60) and the human eye tracking accuracy reaching 60 by preventing the interframe interference and inaccurate positioning.

The rest of this paper is organized as follows. The literature review is discussed in Section 2. Our proposed adaptive BP neural network for predicting eye movement is discussed in Section 3. In Section 4, we provide the experimental results. Finally, the paper is concluded and future research directions are provided in Section 5.

2. Literature Review

Smooth tracking eye movement is a kind of slow eye movement [8]. Eye movement study began very recently and was primarily theoretical at the time [9]. It is now rapidly transitioning to applied research. Professor Yao and his human-computer interaction (HCI) product based on eye movement EagleEyes is a pioneer in the field of eye movement system research, having been one of the first to build accessible HCI technology based on eye movement control [10]. The system also includes a variety of add-on software that allows users to send emails and search for information on their PCs. Professor Gipps has also collaborated with TECCE at the Department of Psychology at Boston University to perform a number of cognitive experiments employing eye movement technologies [11].

Soleymani et al. divided emotions into three groups based on validity and arousal retrieved statistical variables related to pupil diameter and gaze distance and frequency domain features from eye movement signals in a study on participant emotion recognition based on eye movement data [12]. To cross-validate and forecast emotions, the participants utilized a support vector machine (SVM). With proper recognition rates of 68.8 percent and 63.5 percent, the SVM was utilized to predict emotions. The authors proposed not only an eye movement signal feature set for emotion recognition but also a multimodal emotion recognition database MAHNOB-HCI, which includes EEG and eye movement signals [13]. These experimental results show that eye movements can express emotions and eye movement signals can also be used for the study of emotion recognition, which lays the foundation for subsequent studies of emotion recognition based on eye movement signals [14]. The research group also proposed another emotion dataset containing both eye movement and EEG signals, SEED-V, which contains eye movement data from many subjects and contains five human emotions, but the amount of data may still be relatively small and currently inaccessible.

3. Adaptive BP Neural Network for Reading Eye Movement Prediction Analysis

3.1. Adaptive BP Neural Network Design. In this study, we mainly focus on the eye movement signals based on two aspects. First, we judge the subjects' emotions based on their eye movement signals, because it is often said that the eyes are the windows of the human mind, so the expression of human emotions can be seen from the eye movement signals. Although certain results have been achieved, they are not yet ideal. The research on the emotional expression of eye movement is relatively new and there are still certain difficulties, especially while extracting the eye movement information. There are numerous challenges in the extraction and recognition of eye movement signals at present. The extraction of temporal features of eye movement signals has been studied, and the temporal features with the ability of emotion representation are extracted by combining the features of eye movement signals. This paper extracts the abstract features of eye movement information at a high level and uses the adaptive BP neural network to automatically learn the features of eye movement signals for the maximum extraction of signals, which can improve the accuracy of recognition. The algorithm structure is shown in Figure 1.

Earlier, the detection of eye signals was mainly based on human observation, but this was very ineffective and the analysis results were highly inaccurate. With the rapid development of computing, we can use computers to perform waveform analysis. Since the eye movement signals are different and can vary when humans observe different objects or people in different scenes, it is feasible to analyze the eye movement signals using waveform features. When using a computer to observe the eye movement signal, different eye movement information corresponds to different waveforms, so that the amplitude, wavelength, and so on of the signal can be observed for further analysis of the eye movement signal at a later stage.

The analysis of waveforms, as small as the oculomotor signal, is mainly performed using the frequency domain method, which is based on the Fourier transform. The two main types include parametric and nonparametric estimation. In this paper, we mainly use the parametric estimation method to establish the corresponding power spectral density using the following equation:

$$P(w) = \sum_{k=-\infty}^{+\infty} r\left(k^{e}\right)e^{jwk}. \tag{1}$$

An alternative definition of power spectral density is given in the following equation:

$$P(w) = \lim E\left[\frac{1}{N}\left|\sum_{n=1}^{N} x\left(n^{2}\right)e^{jwk}\right]^{2}. \tag{2}$$

Eye movements are mainly divided into eye skipping and blinking. Eye hopping is the process of eye movement from one point to another, which mainly reflects the attention of the eye, learning efficiency, and learning difficulty. It is examined by the speed, in the context of time, and so on. For

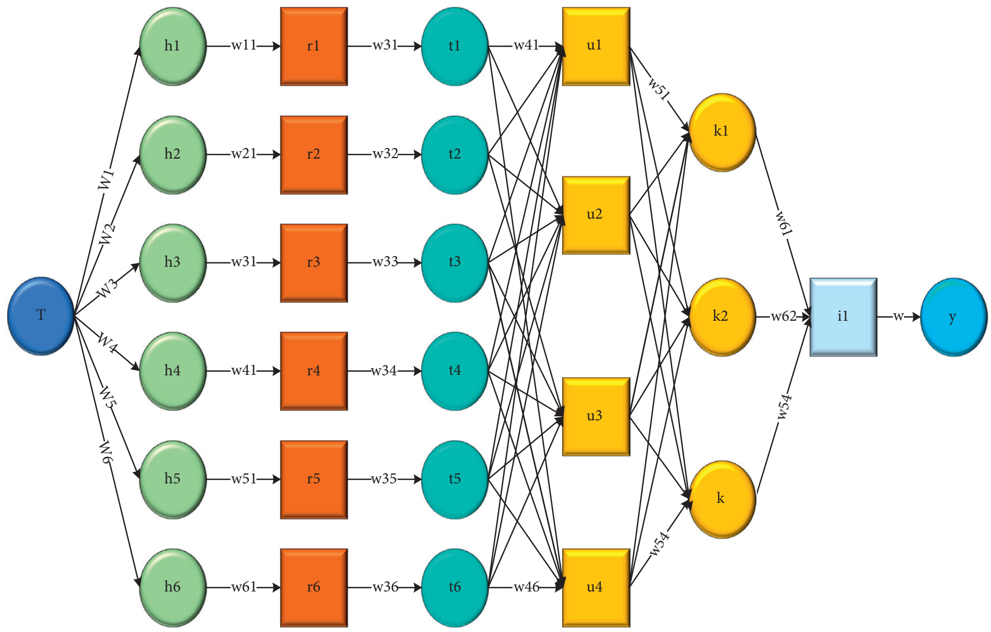


Figure 1: Structure of adaptive BP neural network.

example, when you are reading a book, if you are interested in point A and point B, then you see the distance between the two from point A to point B. We call this the distance of eye darting, if the distance from point A to point B is longer, then the time will also be longer and vice versa. This can also reflect the fatigue of the eyes.

Blinking is a process by which the eyes open and close. In a general sense, blinking reflects a person's fatigue program and is related to its frequency. If a person blinks more frequently and for a longer period, the size of the pupils of the eyes is inconsistent, which in a certain way reflects the person's psychological changes and this change is an important indicator for analyzing the person's mental activity. For example, if a person is more interested in something, the pupils of this person will be dilated, which indicates that the subject is very excited, reflected in the study that the subject wants to learn more knowledge.

Pearson's correlation coefficient (PCC) is a statistical method used to analyze the correlation between variables. For two variables X and Y, the data values obtained experimentally, are expressed as X ($X1$, $X2$, Xi) ($i = 1, 2, 3, \ldots, n$) and Y ($Y1$, $Y2$, Yi) ($i = 1, 2, 3, \ldots, n$). The equation for the average of the two sets of data is shown as follows:

$$E(X) = \frac{\sum_i^n X_i^2}{n},$$
$$E(Y) = \frac{\sum_i^n Y_i^2}{n}, \tag{3}$$

where the covariance is computed using the following equation:

$$\mathrm{Cov}(X, Y) = \frac{\sum_i^n \left(X_i^2 - E(X)\right)\left(Y_i^2 - E(Y)\right)}{n}. \tag{4}$$

The Pearson correlation coefficient is computed using the following equation:

$$p_{x,y} = \frac{\sum_i^n \left(X_i^2 + E(X)\right)\left(Y_i^2 + E(Y)\right)}{n}. \tag{5}$$

Since the MAHNOB-HCI dataset has some noise, we preprocess it before using this dataset. For preprocessing, we use the following equation:

$$X_{\text{data}} = \left[X_{pdl}, X_{pdr}\right]. \tag{6}$$

To test the generalization ability of the experimental model in this paper, we must divide 80% of the sample size as the training set and 20% as the validation set. Then, the above algorithm is used to train the eye movement information data to obtain the corresponding sentiment classification model. The accuracy rate is defined as the ratio of the number of correctly classified samples to the number of all samples classified as positive among the positive samples, as shown in the following equation:

$$P = \frac{N_{\mathrm{TP}}}{N_{\mathrm{TP}} - F_{\mathrm{FP}}}. \tag{7}$$

The recall is defined as the ratio of the number of correctly classified samples among positive samples to the number of all samples classified as positive, and it measures the ability of the classification to correctly classify positive samples as follows:

$$R = \frac{N_{\mathrm{TP}}}{N_{\mathrm{TP}} + F_{\mathrm{FP}}}. \tag{8}$$

$F1$ score is a statistical measure of the accuracy of a binary classification model. It combines both the accuracy and recall of a classification model. $F1$ Score can be considered as a kind of summed average of the accuracy and recall of a model, whose maximum value is 1 and minimum value is 0. $F1$ Score is twice the average of the sum of accuracy and recall, and the $F1$ Score combines the accuracy and recall of a classifier, as follows:

$$F1 = \frac{RP}{R + P}. \tag{9}$$

Sequential data are processed using the memory capability of recurrent neural networks. In traditional neural networks, each layer is fully connected from the input layer to the output layer, but the nodes are not fully connected, and traditional neural networks have poor predictive power for sequential data, where the preceding and following inputs and outputs are not correlated [15]. In recurrent neural networks, the previous information is remembered and preserved and the current output is applied. In the hidden layer, the nodes are connected so that the input of the hidden layer not only is the input of the current input layer but also includes the output of the previously hidden layer, which works well when processing multiple image frames, as shown in Figure 2.

3.2. Experimental Design of Reading Eye Movement. In this paper, we propose a classification method based on eye movements, that is, the eyes can be classified into the following categories during transit: jumping, gaze, and smooth tracking (shown in Figure 3). The main steps are as follows:

(i) Firstly, the inaccurate eye movement data removed upon preprocessing
(ii) Using the speed of eye movements to distinguish between the above-mentioned categories and make them into several segments
(iii) Classification of the obtained data using wavelet transform and vector machines
(iv) Automatic recognition of individual segments using their eigenvalues and clustering algorithms

The above steps mainly get what is more interesting to the user and what is not interesting and what is most interesting or maybe the upper and lower objects are cross-validated with the environment and some additional information obtained. Because the pupil changes when a person is interested in some objects, it is more practical and accurate to use the pupil change to determine the user.

Regarding the dataset we used, this paper uses the cross-missing method for validation. By interpreting the dataset, we can know that, for each subject, we can have the first person perform the eye movement test first and then as a sample and the rest of the people as a model training. This way the accuracy of the emotions of the other subjects can be tested by comparison.

In each eye movement signal, we can extract a sequence of features from it, which then makes up a complete sample. At the same time, we can slide each window, so that each window can also be considered as a smaller sample for easy analysis. Since the whole extracted sample is different, the length of each window is also different, as well as, of course, the number of truncations. These subsamples are mostly from smaller samples and are identical. Using these subsamples, we can have an idea about the complete network input and the output value of the BP neural network and subsamples can be obtained as well. This is shown in Figure 4. Note that it is not desirable if intuitive extraction samples are used.

For a complete waveform in longitudinal pupil coordinates, an upward trend in the waveform indicates upward eye movements and a downward trend in the waveform indicates downward eye movements. When the waveform is segmented, each segment represents the pattern of upward and downward eye movements per unit of time. This time segment includes the amplitude of eye movements and the order of eye movements [16]. For a combination of two segments, the correlation coefficient between the two segments indicates the similarity between the two segments. If correlation coefficients are found between all segments, the sum of these coefficients reflects the sum of similarities between all segments in the longitudinal coordinate waveform of the pupil, that is, the complexity of the combination of all pupil up-and-down movement patterns. In this paper, we use an adaptive BP neural network algorithm to select the segmentation time length and correlation coefficients for each pupil position coordinate waveform when using the combined waveform complexity as the pupil position coordinate feature value.

The delineation of periods is particularly important when extracting the complexity of the integrated waveform. Human response times to different physiological signals of stimulus events may vary between emotional expressions, with heart rate and skin electrical response times to emotional arousal ranging from 3 to 6 seconds. The same emotional reaction times exist for pupil position coordinates, and each time segment of the waveform contains one emotional fluctuation if the length of the time segment can be matched to the smallest unit of the kinetic nerve response. The correlation between segments is calculated in this way; that is, it indicates the degree of correlation of different emotional fluctuations and the sum of the correlation coefficients of all segments within the video temporal degree indicates the combined emotional fluctuations of the subject while watching that video. In other words, it represents the combined waveform complexity.

4. Analysis of Results

4.1. Algorithm Performance Results. From Figure 5, the higher value is the blinking point, and if the fluctuation is not too large, that is, the transition is relatively smooth, then it is the eye gaze point. It is clear from Figure 5 that, by comparing the standard values with the algorithmic results, the BP-based adaptive network algorithm proposed in this paper matches the standard values to a higher standard. In this figure, we can also see that the existing schemes, that is, I-SC, IVDT, and CNN, all show some incorrect classification data and cannot correctly identify the correct trajectory of the eye movement signal. Therefore, the adaptive BP neural network algorithm outperforms the I-SC, IVDT, and CNN

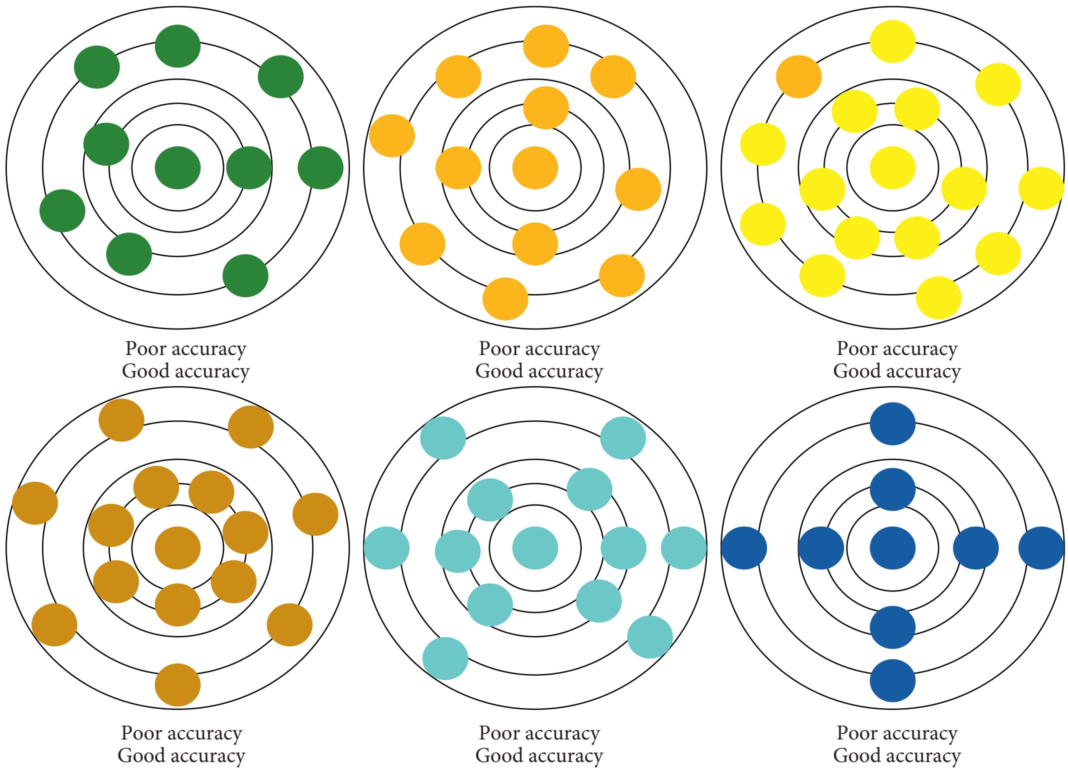


Figure 2: Error analysis model of the line-of-sight tracking system.

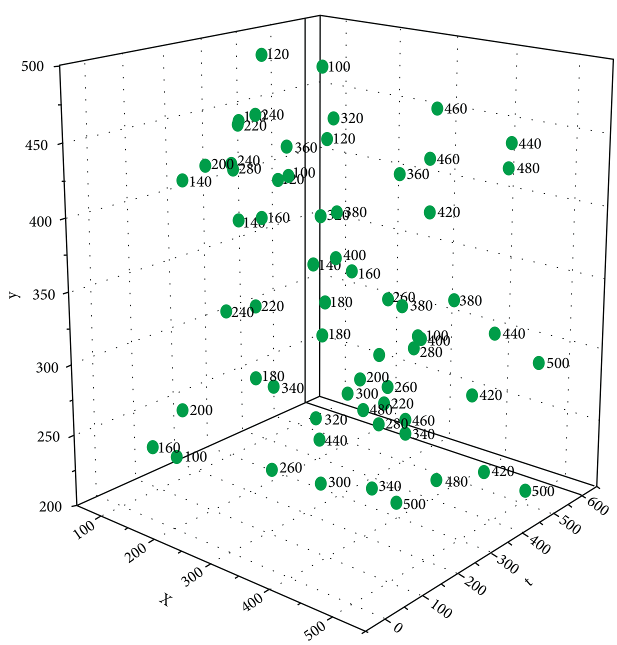


Figure 3: Typical eye movement data with gaze, eye bounce, and smooth tailing.

algorithms in terms of accuracy, recall, and F1 scores for both the initial and intermediate excess and final points of the eye movement signal.

To further analyze the advantages and disadvantages of these four algorithms, white noise is added to the standard

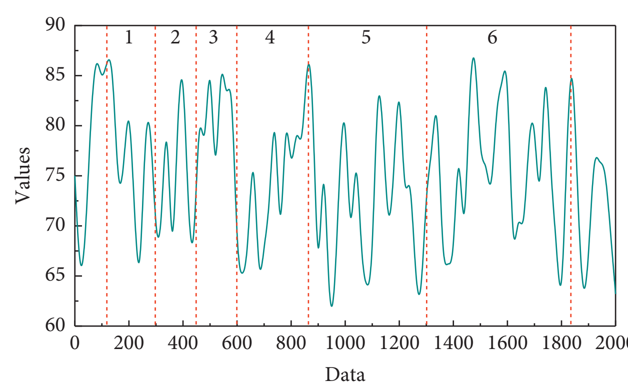


Figure 4: Segmentation of eye movement data.

values in this paper, and the comparison results are shown in Figure 6. In this figure, we can see that the adaptive BP neural network algorithm is effective in classifying eye movement data containing noise due to the consideration of the input values of the eye movement signal and the characteristics of continuity and burst. The simulation results show that the adaptive BP neural network algorithm is effective in classifying eye movement data containing noise. According to the performance metrics of each algorithm given in this figure, the gaze and smooth tailing classification performance of our BP neural network algorithm outperform the other three algorithms in terms of recall and accuracy metrics.

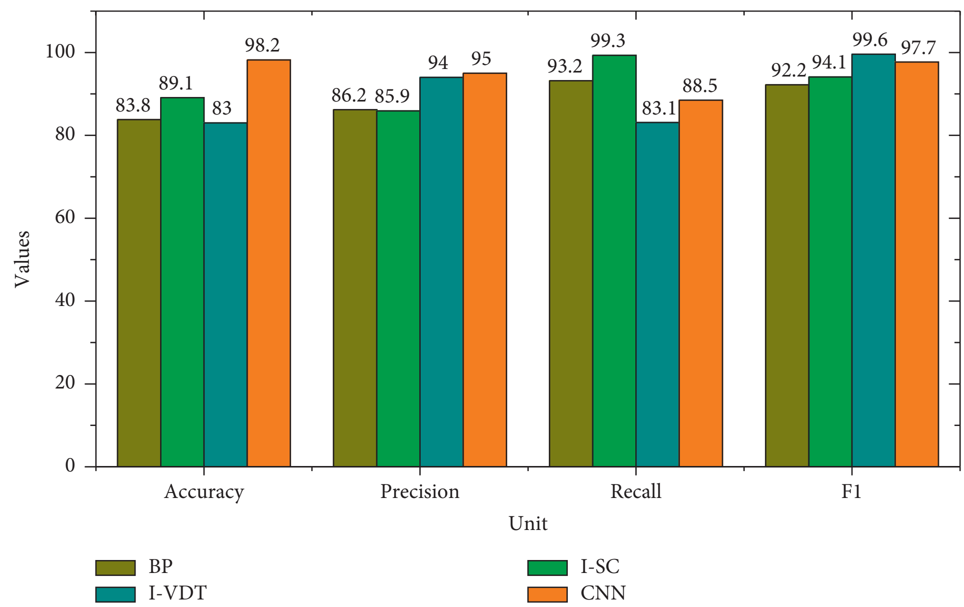


Figure 5: Classification performance on the eye tracking dataset.

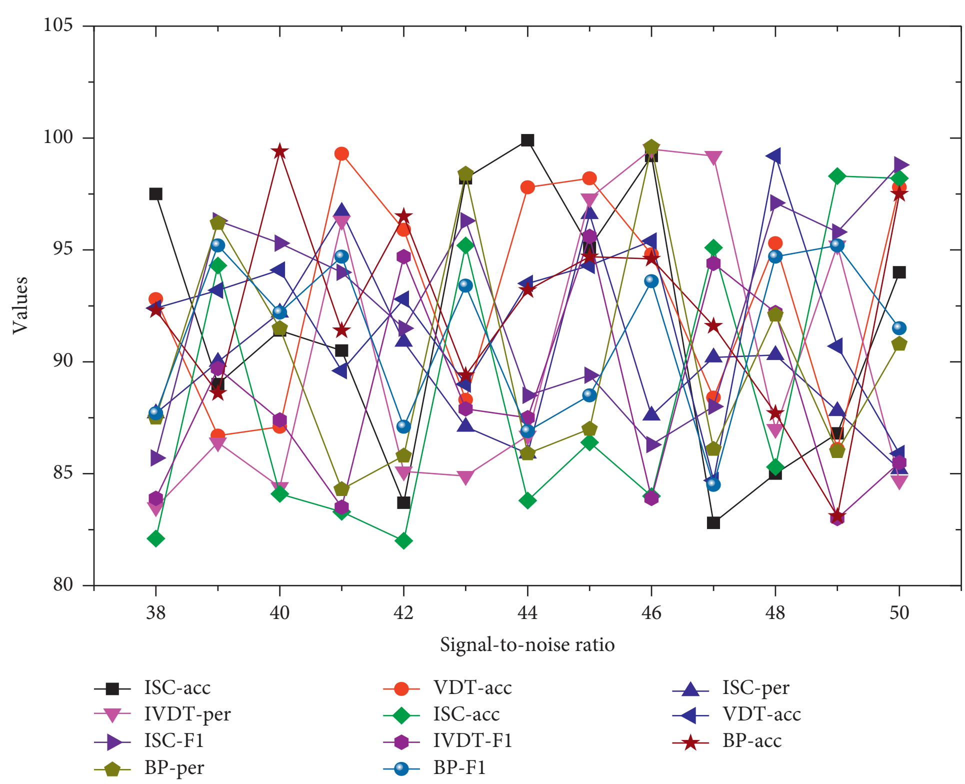


Figure 6: Performance comparison under different noises.

4.2. Analysis of Experimental Results. As shown in Figure 7, the *F*1 values for arousal and validity were compared for all three categories under three different input conditions, indicating that the *F*1 mean value was better than the other two inputs for both arousal and validity. Hence, it indicates that the combined features are more helpful in improving the model performance. This is because the sample size of the high arousal category is much lower than the other two categories, resulting in the model not being able to learn the sample features of this category well and thus not being able to distinguish this category properly. The *F*1 values of the medium arousal category in Figure 7 are both lower than those of the low and high arousal categories, indicating that the model is less capable of identifying medium arousal compared to the other two arousal categories.

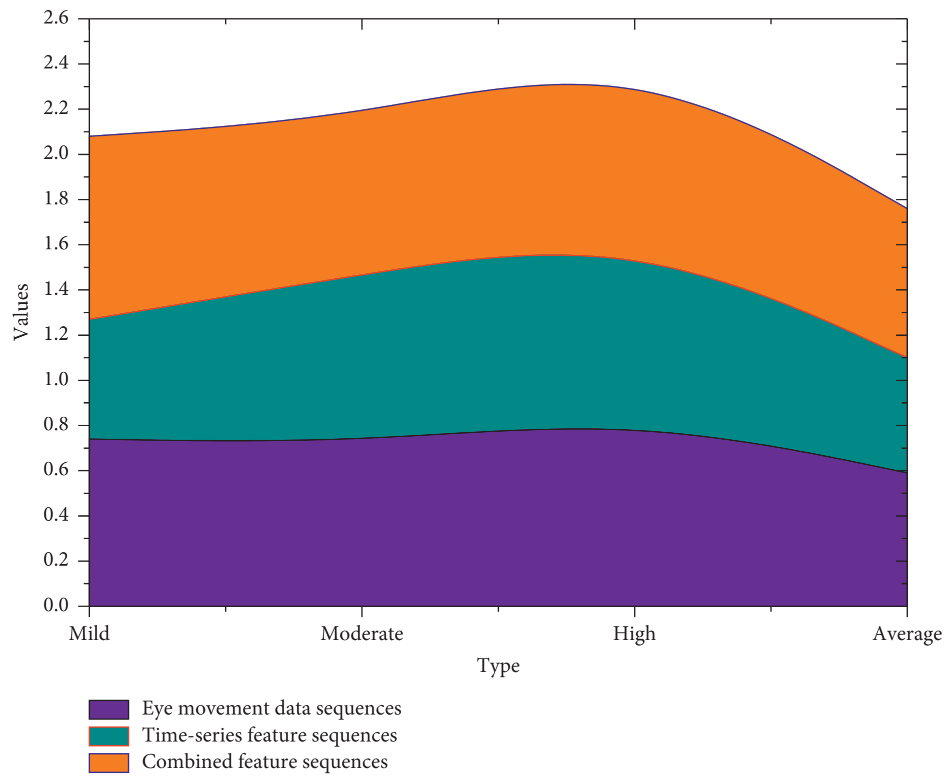


Figure 7: F1 values for three categories of wake-up degree with three different inputs.

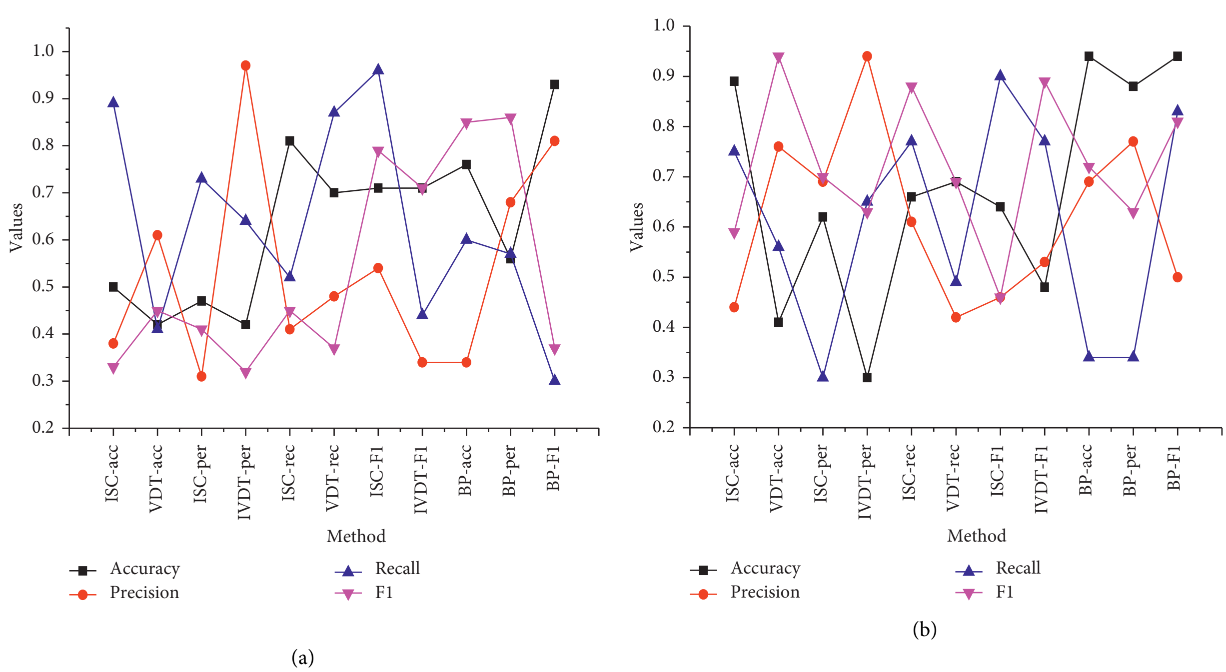
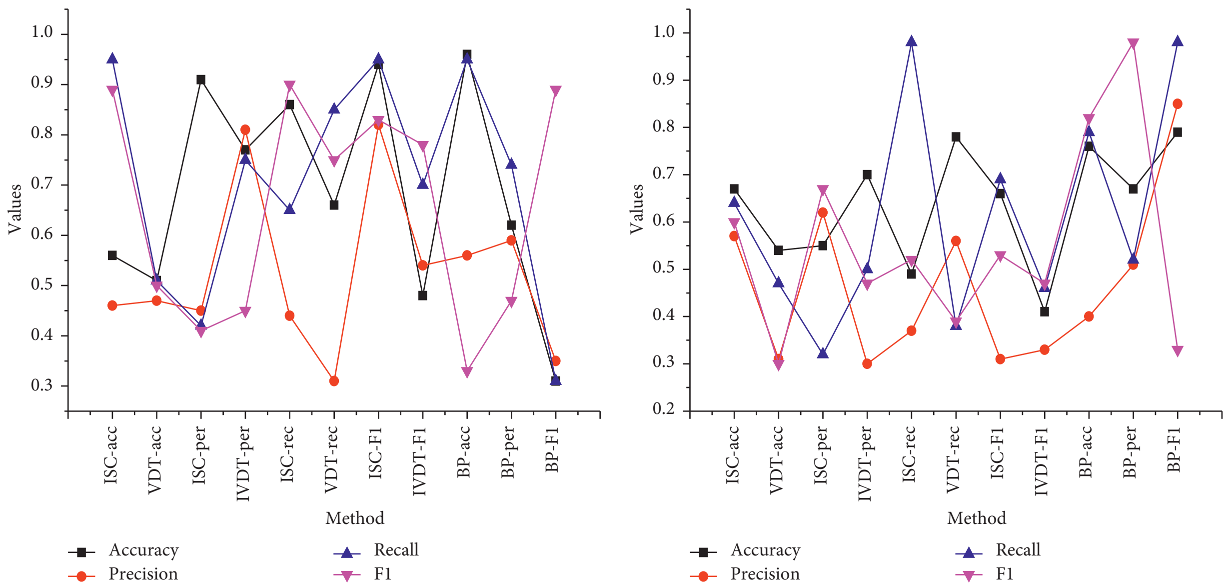


Figure 8: Continued.



(c) (d)

FIGURE 8: Model metrics.

This paper analyzes the problem of the relationship between the temporal performance and the size of the time window of the adaptive BP neural network algorithm proposed in this paper. Generally, we classify the emotional problems generated by eye movements into three broad categories: the emotional initial point, the emotional peak point, and the emotional endpoint. In these three types of emotion points, if we can reasonably allocate the size of each time window, the integrity of emotion can be maintained. The data thus obtained will be more reasonable and the classification recognition will be better. The emotional brain signals we extracted were divided into a total of eight-time windows, their features were analyzed using wavelet methods, and then the vector machines were used to classify each window of emotion. In this experiment, we used 6–15 seconds to obtain 65% accuracy. Thus, the information about emotions in the EEG signal can be properly localized around 6 to 15 seconds. In our experiments, this classifier works better for the 10 s time window dataset, especially in the adaptive BP neural network-based algorithm proposed in this paper; the model gives the best results in the 10 s time window, as shown in Figure 8.

With the BP adaptive neural network algorithm, the distance between the leftward signal and the leftward template is the shortest, and the difference between the templates in the other algorithms is still relatively large. It can also be seen from Figures 8(b) and 8(c), respectively. In Figure 8(d), there is a crossover of signals when blinking twice and blinking once, which means that there is 1 mismatch in 50 datasets with a 98% match rate. The algorithm is not too difficult to implement and is an effective recognition method. The adaptive BP neural network algorithm proposed in this paper is a fuzzy input matching algorithm, which mainly solves the problem of when the input eye movement signal is long or short.

5. Conclusion

This paper's major focus is on the classification and detection of eye movement signals, with the goal of creating a new form of human-computer interaction. To achieve the goal of human-computer interaction, the majority of contemporary human-computer interaction approaches rely on human motion. Human-computer interaction technology based on eye movement signals can effectively tackle the problem of interaction through the eyes, allowing for new technological advancements that will benefit a broader spectrum of individuals. In this paper, the software and hardware environment for acquiring eye movement signals, as well as the acquisition method and electrode pad positioning, were all designed. Four types of eye movement data were collected from ten subjects in the experimental area, and preliminary signal processing was performed. None of the existing studies can address the fact that eye movement signals differ in length and from person to person. As a result, the idea of eye movement signal categorization based on an adaptive BP algorithm is proposed, which not only handles this problem well but also shows in simulation results that it may significantly enhance recognition rate.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this study.

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Research Article

Application of Random Forest Algorithm in Physical Education

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Learning has been a significant emerging field for several decades since it is a great determinant of the world's civilization and evolution, having a significant impact on both individuals and communities. In general, improving the existing learning activities has a great influence on the global literacy rates. The assessment technique is one of the most important activities in education since it is the major method for evaluating students during their studies. In the new era of higher education, it is clearly stipulated that the administration of higher education should develop an intelligent diversified teaching evaluation model which can assist the performance of students' physical education activities and grades and pay attention to the development of students' personalities and potential. Keeping the importance of an intelligent model for physical education, this paper uses factor analysis and an improved random forest algorithm to reduce the dimensions of students' multidisciplinary achievements in physical education into a few typical factors which help to improve the performance of the students. According to the scores of students at each factor level, the proposed system can more comprehensively evaluate the students' achievements. In the empirical teaching research of students' grade evaluation, the improved iterative random forest algorithm is used for the first time. The automatic evaluation of students' grades is achieved based on the students' grades in various disciplines and the number of factors indicating the students' performance. In a series of experiments the performance of the proposed improved random forest algorithm was compared with the other machine learning models. The experimental results show that the performance of the proposed model was better than the other machine learning models by attaining the accuracy of 88.55%, precision of 88.21%, recall of 95.86%, and $f1$-score of 0.9187. The implementation of the proposed system is anticipated to be very helpful for the physical education system.

1. Introduction

Education is an important and a fascinating field which grows over the years and has a significant impact on everyone's life. Numerous techniques and methods were proposed to develop high quality experiences that benefit the entire educational sector, starting with learning and advancing toward E-learning. The route to improvement often needs extra hands to bring alternative perspectives and modifications, which can be done with the help of the crowd. Student/learner assessment is one of the most important practices in the educational field. Educational assessment is a technique used to evaluate a learner's degree of knowledge and enhancing his or her learning during the course. This process has a significant impact on students' motives, development, and learning practices and has been called "one of the most powerful forces impacting education" by Crooks [1]. Similarly, Harlen et al. [2] asserted that "assessment feedback plays a significant role in predicting future learning," as it has a direct impact on students' performance and persistent effort in future projects.

In the earlier approaches of students and teachers performance evaluation systems, in most of the cases, people have used the total score or average score to evaluate the students in the college teacher evaluations throughout the last few decades. This is a very simple and easy method to implement and is still the fundamental evaluation method in numerous colleges and universities in different countries. However, in today's era of advocating students' personalized and diversified development, especially in profession selection, it is very important to fully understand students' ability, characteristics, and comprehensive indicators in all aspects, and many people pay attention to and study them in the recent years [3–5].

In the higher education evaluation methods, it has been clearly pointed out that a reasonable and scientific evaluation system should be established for college students, including evaluation concepts, evaluation contents, evaluation form, and evaluation system. The evaluation process needs to be focused on both the student's mathematical learning as well as the learning process. The student's learning should not be the only point of attention, but the changes of their emotional attitude in the activities should be kept in consideration [6]. Among the key goals of curriculum reforms in China one is to establish an assessment system with multiple objectives and methods. The primary goal of evaluation is to fully understand the process and results of students' learning and encourage students to learn and give feedbacks to the teacher, in order to improve the teachers' teaching strategies [7–10]. Therefore, how to investigate an effective teaching assessment method in order to better serve teaching is a problem that needs more investigation. At the same time, the grade evaluation of students' performance is the most important content in teaching evaluation from beginning till now.

Machine learning (ML) is an important field of artificial intelligence (AI) which can be applied in various fields such as healthcare, industries, agriculture, media, and education, etc., and it helps to improve all of its connected tasks by giving real-time responses that save time and eliminate the need for manual intervention of users in an effective manner [11, 12]. Various methodologies are being used in the education sector to attain their goals, including various ML supervised learning algorithms and natural language processing (NLP) techniques. Therefore, in order to overcome the problems of the traditional systems, this study uses classical multivariate statistical method factor analysis and an intelligent ML iterative random forest algorithm. Further, the establishment of a comprehensive assessment model of physical education teaching is of great theoretical and practical significance for the real-time grasp of students' learning situation and the improvement of teaching methods. When we have a reasonable "evaluation model of students comprehensive performance," we can more intuitively understand which factors play a leading role in students' performance, and then we can make a comprehensive and objective evaluation of students' physical education teaching performance. Through the understanding of students' learning situations, the teachers can teach more targeted stuff and content and can help every student as much as possible. At present, the research of data mining and ML in the field of education mainly focuses on the exploration of learning environments, network-based teaching systems, improving students' performance, and other fields. In the earlier approaches the application of information mining for student evaluation is almost negligible which indeed is a serious problem. This paper studies the potential of data mining and ML in the measurement of teachers' performance perceived by the students. Four commonly used ML classifiers, namely, decision tree (DT), support vector machine (SVM), Naïve Bayes (NB), and random forest (RF), are selected to model the dataset of students' online evaluation course information. Further, the performance of various classification techniques is compared [13–16]. The main contribution of this research study is given below:

(1) This study proposes a novel approach of factor analysis and random forest algorithm to reduce the dimensions of students' multidisciplinary achievements in physical education into a few typical factors.

(2) Several experiments have been performed for various ML classification algorithms in order to check the performance and stability of the proposed system.

(3) Performance of all the utilized ML models has been evaluated in terms of numerous performance measurement metrics such as accuracy, precision, recall, and $f1$-score.

(4) This study recommends which ML classifier is more feasible in order to develop a high level intelligent system for the student physical education.

(5) From the experimental results it is obvious that the performance of the proposed system is much better than the traditional student physical education systems.

The remaining paper is structured in the following order. Section 2 represents the related work. Section 3 shows the material and methods. Section 4 illustrates the experimental results and analysis. Section 5 concludes the proposed work.

2. Related Work

The research field is one of the most important parts of education and has a great influence on the education of a country. The paucity of resources needed to conduct professional research can be avoided by assembling a group of researchers who can pool their resources and do joint study. Numerous platforms have been established to assist students in sharing their ideas and contributing to a big research group comprised of many researchers, each of whom performs a different character [17]. Enhancing the research field could usher education into a new era by bringing together all of the knowledge from many fields of expertise, raising the educational instruments to a new level. Further, it can also assist in giving the ideal learning experience by investigating all the flaws in various areas and can offer valuable suggestions to improve them. The mining contacts among students in online education are another serious issue of education. One of the proposed systems addresses this problem by providing a peer-to-peer debate system that lets the students from various regions share their knowledge depending on their own areas and countries [18]. Another framework was discovered to improve online course interaction by allowing the crowdsourcing technique to provide timely response on online student submissions [19]. All the proposed systems have the potential to increase the learning process and provide opportunities to those students who have limited learning opportunities and are depending only on the online courses for continuing their education. As a result, concentrating on student engagement is critical to the learning process' efficiency. As a result, because the offered solutions are entirely reliant on nonexpert personnel, the process must be closely monitored to avoid supplying incorrect information or providing inaccurate feedback.

In the learning process, establishing a personalized learning goal is indeed a critical task. To accomplish this purpose, Whitehill and Seltzer [20] proposed a platform for online learning videos where crowd-sourced videos are developed and filmed by common people rather than professional professors. Faisal et al. [21] proposed a framework that assists the learners in selecting the appropriate learning plan based on a recommendation system, where the desired learning activity is different depending on the learner's attributes. Alghamdi et al. [22] proposed a system in which they attempted to produce exam questions of high quality. To produce large-scale tests in a professional context, this platform can incorporate as many teachers as feasible in the process of creating and evaluating question items. One of the approaches presented by De Alfaro and Shavlovsky [23] allows students to submit assignments and review and grade them collectively. This technique provides students with an overall crowd-grade, which assures the quality of their homework as well as their reviewer effort. The students can answer the test questions on another system, which uses a specific algorithm to assess the complexity and validity of the questions generated. [24]. In a similar manner, Pirttinen et al. [25] presented an embedded tool for online courses that allows students to generate assignments while also reviewing and evaluating each other's work. Farasat et al. [26] proposed the concept of crowd-learning, in which students might learn more deeply by generating their own educational materials. They presented an online platform as a solution for it that can be utilized for in-class practice or online classes. Among all of the previous ways, the evaluation process, which is the primary means of evaluating any student, can become extremely delicate. Total reliance on the audience for grading may result in grades that are unfair or erroneous.

ML can be implemented into any field to improve all of its related activities by giving real-time replies that save time and eliminate the need for manual intervention. To reach their aims in the education sector, many systems are leveraging different ML models such as supervised or natural language processing (NLP). For their preferred schemes, many approaches used supervised ML models. A system was presented to autonomously examine the effectiveness of community question answers, which uses a classification technique to evaluate the quality of every answer by examining a set of various criteria [27]. Classification algorithms are mostly supervised learning algorithms that learn from the patterns of the input data and then produce output based on the learned knowledge. The proposed method begins with feature extraction and the collection of historical data about the community member, which will aid in the development of the categorization model. Finally, the trained models will be used to assess the quality of all new answers. Li [28] suggested a method that used a supervised model and followed a regression technique, with the output variable having a continuous and real value. By using the model to identify the key variables affecting the student's learning performance, the author hoped to gain a better understanding and analysis of the reasons behind each student's results. As a result, teachers will be able to track the learning effect and change their teaching technique to meet the demands of their students using this method. The supervised model is completely reliant on the teaching practice and previous experiences. The offered collection of data is the user's previous experience with a computer language. If the improper collection of data is used to train, the results may be inaccurate, affecting the suggested approach's intended use. As a result, the problem for each new educational research is to choose the correct data with the right model because it is critical to its success. In the studied literature, one of the platforms that employs NLP is a web-based application that visualizes the output from a ML-based model trained to guess MCQs, with the primary purpose of identifying and manipulating questions within a well-organized and high quality bank of MCQs [29]. Furthermore, NLP is utilized in the exam evaluation process to compare the similarity of students' answers to the perfect answer when the ideal solutions are accessible. The proposed method will compute the student's recommended score as a consequence of this comparison [30]. This paper investigated the potential of ML in the measurement of teacher's performance perceived by the students. Four ML models, i.e., NB, SVM, DT, and improved RF, are used on the students' online evaluation course information dataset. The improved RF showed sublime performance in terms of various performance measures.

3. Material and Methods

This section of our study represents the methods followed and the material used for the conduction of the research study.

3.1. Data Set Collection and Characterization. The data collection process is an important step for building an intelligent system. In this study, the recent 3-year student physical education data is selected which comprises 3216 randomly selected instances in which 2000 were positive samples while the remaining 1216 were negative samples of data. Each data instance has 28 attributes, which come from students' online scores, involving physical education teaching preparation, physical education teaching performance, teaching methods implementation, case organization, curriculum implementation, teachers' attitude, curriculum construction, and so on. The evaluation indexes are shown in Table 1.

3.2. The Classification Models Used in This Study. One of the most popular applications of data mining and ML is the classification. The main task of classification is to assign a

Table 1: Description of different evaluation indexes.

Attributes	Description	Value range
V1	How often do you take this course?	1~5
V2	The teacher is well prepared before class?	1~5
V3	Does the teacher come to class on time?	1~5
V4	Do teachers often encourage students to ask questions? Participate in the discussion?	1~5
V5	The teacher has a good grasp of the subject?	1~5
V6	Is the teacher approachable and easy to communicate?	1~5
V7	Is the teacher effective in organizing the materials in the demonstration, lectures, and discussions?	1~5
V8	Homework helps me?	1~5

class label among possible categories for a sample represented by a set of feature vectors and is accomplished by a classification model. The model constructs a learning algorithm on a training set, in which the class label of each instance in the training set is known before training. At the end of the learning phase, the test set is used to evaluate the performance of the classification model. Decision tree algorithm is one of the classical ML classification algorithms, which classifies and induces data through a top-down and clear-cut process. The purpose of the decision tree algorithm is to recursively divide the observation results into mutually exclusive subgroups until there is no difference in the given statistics. Information gain, gain ratio, and Gini index are the most commonly used statistics for finding classification attributes of different nodes of the tree. Generally, iterative dichotomy (ID3) uses information gain, C4.5 and C5.0 (the successor of ID3) use gain ratio, and classification and regression tree (CART) uses Gini index. Support vector machine (SVM) tries to find a hyperplane to separate classes, minimize the classification error, and maximize the edge. SVM is a good classification and regression technology proposed by Vapnik at Bell Laboratories. SVM has four kernel types including linear, rbf, sigmoid, and polynomial. The use of kernel type depends on the nature of the problem. Among the kernel types linear and rbf are the most commonly used kernel types of SVM. Naïve Bayes (NB) classifier classifies samples by calculating the probability that an object belongs to a certain category. The theoretical basis of classification is Bayesian theorem. According to the Bayesian formula, the posterior probability is calculated according to the prior probability of an object, and the class with the largest posterior probability is selected as the class of the object. In other words, Bayesian classifier is the optimization in a sense of minimum error rate. Random forest (RF) is a kind of ensemble learning classification algorithms, which integrate the classification effect of multiple decision trees. It consists of multiple base classifiers, each of which is a decision tree (DT). Each DT is used as a separate classifier to learn and predict independently. Finally, these predictions are integrated to get the total prediction which is better than a single classifier. Figure 1 shows the basic diagram of the utilized ML classification models training and testing process.

3.3. The Proposed Random Forest Classification Algorithm. Random forest (RF) algorithm is an integrated learning method proposed by Leo Breiman and Adele Cutler, which means that it is composed of many small submodels, and the output of each small submodel is combined to give the final output. RF algorithm is a typical ML algorithm, which is usually used for classification, regression, or other learning tasks. The RF algorithm is based on bagging algorithm to group data from the original dataset. After training for each group, the corresponding decision tree model is obtained. Finally, all the decision data results of the subsmall models are combined and analyzed to get the final RF model. The final prediction result of the RF algorithm is based on the voting algorithm, and the classification with the largest number of votes is the final output of the RF algorithm [31–35].

By using multiple classifiers for voting classification, RF algorithm can effectively reduce the error of a single classifier and improve the classification accuracy [36–42]. Practical experience shows that, compared with artificial neural network (ANN), regression tree, SVM, and other algorithms, RF algorithm has higher stability and robustness, and the corresponding classification accuracy is also in the leading level. RF algorithm is efficient for large-scale data processing and can adapt to high-dimensional data application scenarios. At the same time, it can still maintain high classification in missing data scenarios. The style and working process of RF algorithm are shown in Figure 2.

Compared with other classification algorithms, RF algorithm has better classification performance. It can process large-scale data, support large-scale variable parameters, and intuitively evaluate the importance of variable features. More and more algorithm competitions and practices have proved that the RF algorithm has a high classification performance and has better robustness and stability while maintaining high efficiency [43–46].

3.4. Applications of Different ML Algorithms in the Prediction of Students Course Performance

3.4.1. Description of Student Achievement Dataset. There are many factors that affect the physical education teaching. Among them, there are some uncontrollable factors and controllable factors, which directly or indirectly affect students' performance. This study attempts to integrate the improved RF algorithm into the prediction data of physical education teaching, through the improved RF algorithm to more accurately predict the students' physical performance in order to focus on the factors that affect students'

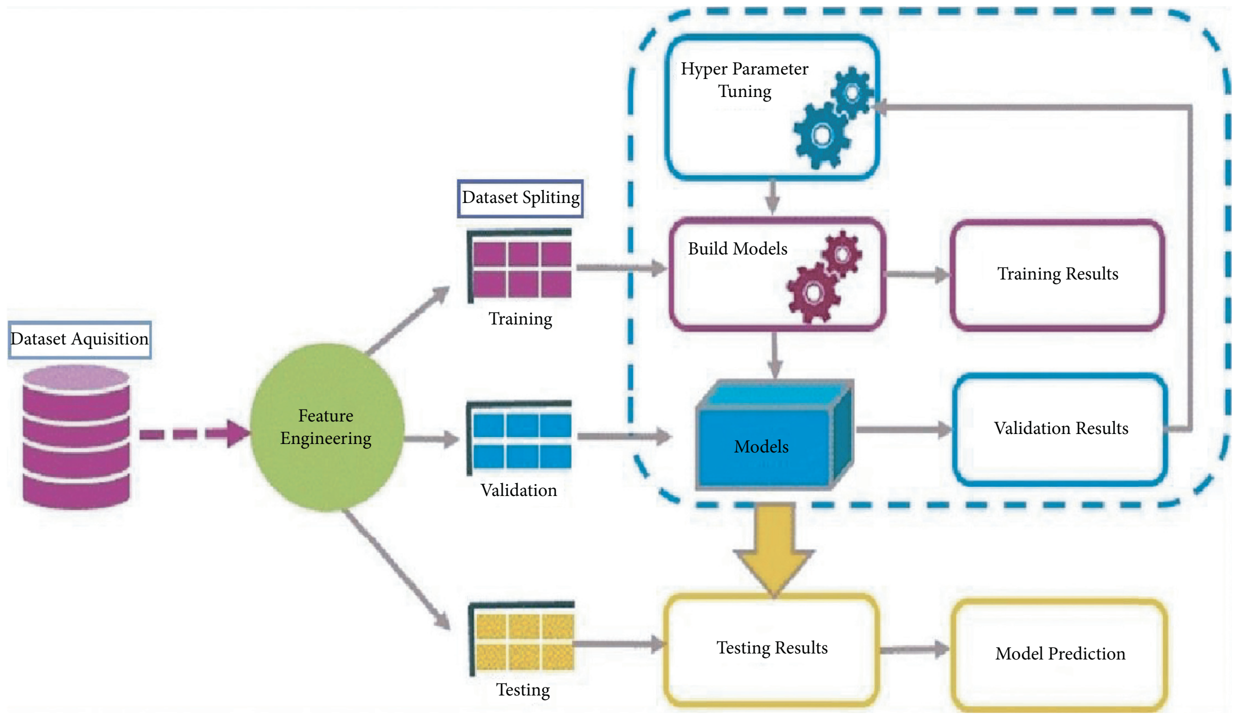

FIGURE 1: Basic diagram of the utilized ML classification algorithms.

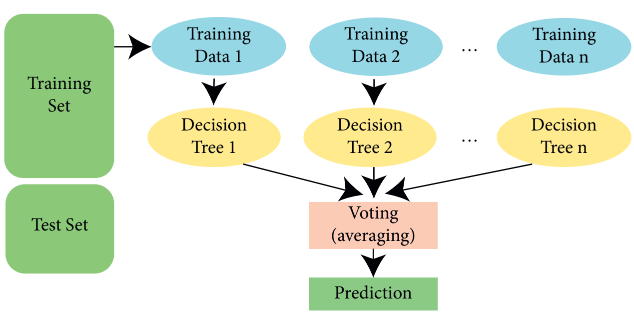

FIGURE 2: Working process of the RF algorithm.

performance and to focus on the process of curriculum reform. We firmly believe that the continuous cycle of this prediction practice improvement way can promote the school teaching reform, promote the level of school physical education to be more scientific and efficient, at the same time make the students' performance more excellent, and enhance the competitiveness of students' job opportunities after graduation. The description of student achievement dataset is shown in Table 2.

In this paper, the dataset selected for the experimental work is the student achievement dataset. The dataset of students' achievement and characteristics was collected from the course of college students' public physical education. The dataset includes 9 characteristics/attributes of students. The nine characteristics are divided into three categories, i.e., students' statistical characteristics, educational background characteristics, and students' behavior characteristics. The classification of students' behavior characteristics includes students' activity in the class, i.e., students' absence, the number of times students visit teaching resources after the class, the number of times the students participated in the course discussion, and students' satisfaction from the course. In addition, the course also collects students' course scores, which are divided into two categories: positive (score between 60 and 100) and negative (score below 60).

3.4.2. Normalization and Characterization of Dataset Features. The dataset is collected by the author from daily physical education work, which involves multidimensional original data collection. The work involves a long time range, and the workload is relatively large. Then, the data preprocessing for the original data is carried out, including data cleaning, data discretization, removal of missing values, data filtering, and so on. Due to the differences and diversity of the expression forms of the collected data, it is necessary to preprocess the data: for unreasonable data or illegal data, the records should be cleaned out. For a wide range of characteristic data, "students' curriculum activity," discretization, and normalization are needed.

Feature normalization is mainly to scale and normalize the feature value, so that the feature value is reduced to a specific range, such as [−1.0, 1.0] or [0, 1.0]. The work of feature normalization helps to reduce the excessive difference of different feature value ranges and the dependence of the algorithm on feature measurement units. Feature normalization mainly uses linear transformation, log transformation, Tan transformation, and other methods for data standardization, so as to transform the data into a small common space.

For the data of students' comprehensive scores, the characteristic variables need to be planned, while the other characteristic variables are calculated with the original

Table 2: Characteristics of student achievement dataset.

Serial number	Meaning	Features	Value description
1	Teaching objectives	Mubiao	{0: OK; 1: Bad}
2	Teaching method	Fangfa	{0: OK; 1: Bad}
3	Exercise intensity	Yundong	{0: OK; 1: Bad}
4	Organizing teaching	Zuzhi	{0: Bad; 1: General; 2: OK}
5	Demonstration capability	Shifan	{0: OK; 1: Bad}
6	Responsibility	Zeren	{0: OK; 1: Bad}
7	The atmosphere of physical education	Qifen	{0: OK; 1: Bad}
8	Venue equipment	Qicai	{0: No; 1: Yes}
9	Teaching effectiveness	Xiaoguo	{0: OK; 1: Bad}

values. For the characteristics of students' absence times, the feature programming method mainly uses the maximum and minimum normalization method and linear transformation of memory. Next, we choose the most representative student sports teaching activity as an example to illustrate the complex characteristics of standardization. For the characteristics of students' active degree of physical education teaching, it is mainly to collect the number of users' hands raised to answer the questions, the number of exchanges in physical education teaching, and the degree of personal physical education teaching concentration for comprehensive evaluation. In the process of implementation, the discrete data is normalized to [0, 1] based on the log function standardization method, and each factor is assigned the corresponding weight coefficient, so as to get the data of students' physical education activity. The expression of students' active degree in physical education teaching is given as follows:

$$\begin{aligned}\text{KTScore} = W_{js} * \frac{\log_{10}(JSx)}{\log_{10}(\max JS)} + W_{jl} * \frac{\log_{10}(JLx)}{\log_{10}(\max JL)} \\ + W_{ZZ} * ZZ\text{Factor},\end{aligned} \tag{1}$$

where W_{js}, W_{jl}, and W_{ZZ} represent the weight coefficients of the three factors, which are set accordingly to 0.5, 0.2, and 0.3 by default, and ZZFactor indicates that the teachers evaluate the students' concentration subjectively, and its value is also between 0 and 1.

3.5. Performance Evaluation Metrics. There are many performance measures to evaluate the performance of the classification models according to the correctness of classification decision. Suppose that, in a binary class task, class variable values can be assumed to be positive (P) or negative (N). The actual positive cases (P) correctly classified by the model as positive cases are named as true positive (TP) cases, and when the actual positive cases are wrongly classified by the model as negative cases they are named as false negative (FN) cases. In a similar way, the actual negative cases (N) correctly marked as negative cases by the model are regarded as true negative (TN) cases, while the actual negative cases wrongly marked as positive cases by the model are regarded as false positive (FP) cases. These terms are given in the confusion matrix as shown in Table 3.

Table 3: Confusion matrix.

	Predicted (−)	Predicted (+)
Actual (−)	TN	FP
Actual (+)	FN	TP

Formulas (2)–(5), respectively, give the calculation results of performance metrics, such as accuracy, precision, recall, and $F1$-score.

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{FP} + \text{FN} + \text{TN}} * 100\%, \tag{2}$$

$$\text{Precision} = \frac{\text{TP}}{\text{TP} + \text{FP}} * 100\%, \tag{3}$$

$$\text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}} * 100\%, \tag{4}$$

$$F1\text{ score} = 2 * \frac{\text{precision} * \text{recall}}{\text{precision} + \text{recall}}. \tag{5}$$

4. Experimental Results and Analysis

This section of the paper demonstrates the experimental results attained via different ML classification models. The performance of each ML model is then analyzed with the help of various performance metrics. Figure 3 shows the platform infrastructure of the experimental environment. The platform consists of both the hardware and software components and is carried out via various software configurations on the basis of hardware environment. PostgreSQL is used as a data storage platform to store the data sets and provides data sources for the R language programs. R is used as a language for the implementation of all the ML classification models and R-Studio IDE environment is used to write the relevant algorithm code to realize the improved RF algorithm.

The experimental environment of this paper basically consists of the two parts, i.e., software and hardware. The software part is mainly Linux 64-bit operating system, the database is PostgreSQL relational database, the programming language used is the R language, and the IDE environment is R-Studio. In addition, there are some other software, whose configuration and version description are shown in Table 4. The hardware part includes a computer

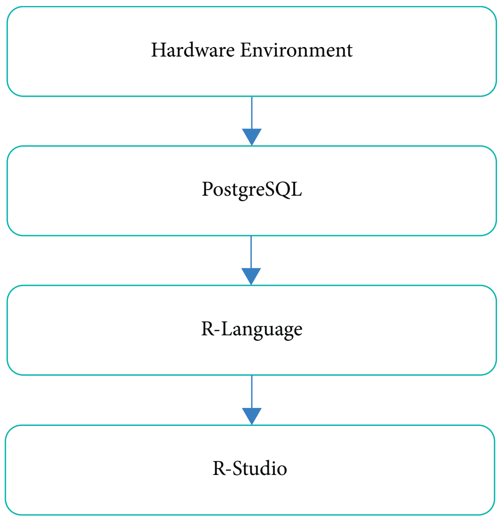

FIGURE 3: Experimental platform infrastructure.

TABLE 4: Software configuration and environment platform.

Function	Software version
Database	PostgreSQL 9.6.12
IDE environment for R development	R-Studio 1.1363
R language	R3.1
Database backup tool	Pg_dump
Database import tool	Pg_restore
Data synchronization tool	Sync
Code management tools	Git
Document authoring tools	VIM, Office

system having the specification: Intel Core i7, 3.4 GHz processor, 16 GB RAM, and 256 GB SSD.

4.1. Experimental Results of All the Investigated ML Classification Models

4.1. Experimental Results of All the Investigated ML Classification Models. This subsection represents the experimental results attained via the investigated ML classification models using the students' achievement dataset. Table 5 shows all the experimental results attained by the utilized ML classification models.

Table 5 shows that the proposed iterative RF algorithm performed really well by attaining the accuracy of 88.55%, precision of 88.21%, recall of 95.86%, and $f1$-score of 0.9187. The second best results were observed for the LR model. LR attained the accuracy of 87.99%, precision of 89.19%, recall of 93.90%, and $f1$-score of 0.9148. The lowest performance was observed for the GRNN model. GRNN achieved the accuracy of 84.35%, precision of 86.40%, recall of 90.75%, and $f1$-score of 0.8852.

Figure 4 shows the accuracy, precision, and recall results while Figure 5 illustrates the $f1$-score results of all the investigated ML classifiers used in this study.

From Figures 4 and 5, we can see that the RF algorithm has advantage over the other algorithms in terms of the mentioned performance measures using the student characteristics dataset.

TABLE 5: Experimental results of all the investigated ML classification models.

Measures	LR ($C = 1$)	NB	SVM (kernel = "rbf")	GRNN	RF
TP	231	214	223	216	232
FN	15	32	13	22	10
FP	28	24	42	34	31
TN	84	88	80	86	85
Accuracy	87.99	84.36	84.64	84.35	88.55
Precision	89.19	89.91	84.15	86.40	88.21
Recall	93.90	86.99	94.49	90.75	95.86
$F1$ score	0.9148	0.8842	0.8902	0.8852	0.9187

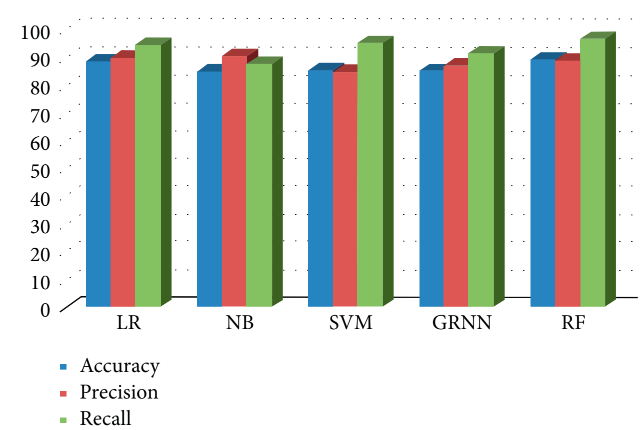

FIGURE 4: Performance (accuracy, precision, and recall) of all the investigated ML models.

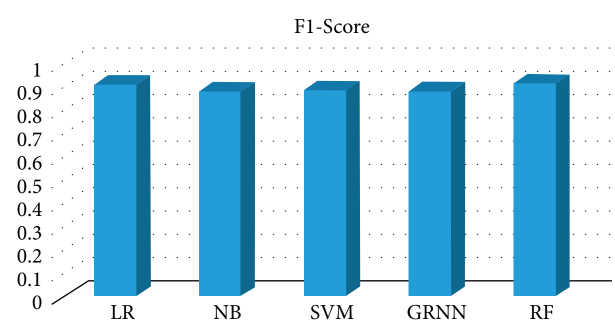

FIGURE 5: $F1$-score of all the investigated ML classification models.

4.2. Algorithm Evaluation and OOB Simulations. In the evaluation process of improved RF algorithm (IRFC), the same parameter configuration was used, and the common parameter settings are maxgen: 20 and $T_{\max} = 10$. In the process of algorithm performance evaluation, the average method of 10-fold cross validation was used to calculate the value of each index. For the dataset of students' characteristics, our main idea is to construct a dataset based on the behavior records of historical students and subject scores (three-year data), select the scores of the first two years as the training set, train the parameters and characteristics based on the improved RF algorithm, and predict the scores of the last year as the test set and compare them with the real score classification. The scale of the student achievement dataset (three years) was 2002.

Reducing the OOB error is one of the goals of the improved RF algorithm proposed in this paper. Figure 6 shows the OOB error comparison chart of the improved RF algorithm in UCI dataset and student comprehensive score dataset.

The abscissa of the improved RF algorithm is $k = 1$, m, $\sqrt{M}\ \log 2(M) + 1$, and the ordinate of the improved RF algorithm is the OOB error value. It can be seen from the figure that the OOB error value of the IRFC is obviously lower than that of the traditional fixed parameter values. Through the verification of the above two datasets, it also shows that the fixed k value of the traditional RF algorithm is not the optimal scheme, which has a great impact on the performance of the algorithm, and its tuning can significantly improve the performance of the algorithm. The improved RF algorithm also provides a reference method to optimize the value of k parameter. Figure 7 shows the relationship between OOB error and the number of decision trees.

In order to verify the influence of the number of decision trees on OOB error, we calculate the corresponding relationship between the number of decision trees and OOB error in the calculation process of the improved RF algorithm, as shown in Figure 6. As can be seen from the figure, OOB error decreases rapidly between 0 and 300 decision trees and reaches stability between 300 and 600 decision trees. From the previous results, the improved RF algorithm achieves the best performance on 339 decision trees.

The improved RF algorithm in the previous sections is developed in R-Studio IDE environment based on R language. It can complete the training in an acceptable processing time when processing the current small-scale datasets, but it will show a very slow model training process when the data scale is relatively large. In addition, since we will carry out many years of data training and prediction of large-scale courses in the future, we must also consider the efficiency of algorithms in large-scale data.

In order to improve the efficiency of the improved RF algorithm, this paper plans to use the task parallelization mode to improve the classification speed of the algorithm. In this study, the parallel processing mode of SparkR is used to process the algorithm, and the data set of students' performance is processed in the cluster environment. The improved RF algorithm of parallel transformation is used to predict the final performance classification of students' physical education teaching. The cluster environment consists of four servers, one of which is the master (driver) node, and the other three are the slave (worker) nodes. The basic configuration of each server is CentOS 6.8, spark version is 2.2, memory is 16 GB, and CPU model is Intel Core i7 and 3.4 GHz processor. In order to implement the improved RF algorithm in parallel based on SparkR, it is necessary to adjust the algorithm properly, so that it can be executed in parallel. The parallel strategy of improved RF algorithm includes the parallel strategy of RF algorithm and the parallel strategy of simulated annealing algorithm.

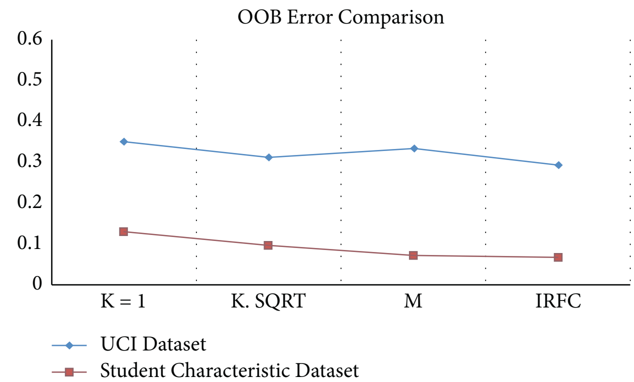

Figure 6: Comparison effect of OOB error.

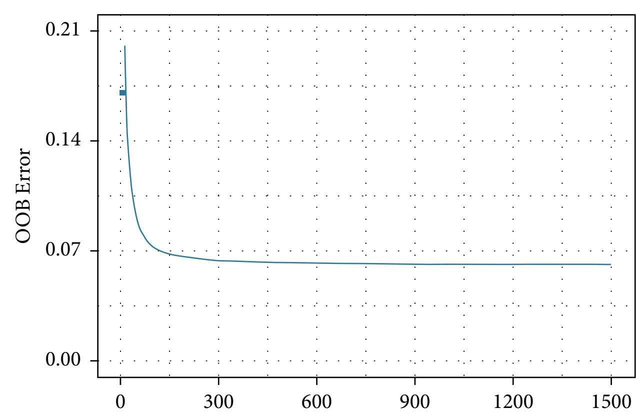

Figure 7: Relationship between OOB error and the number of decision trees.

Parallel strategy of RF algorithm: the decision tree construction in the execution process of RF algorithm is evenly distributed to each node in the cluster, so that the construction of decision tree can be executed in different cluster nodes, so as to realize the execution parallelization of decision tree. On each node, the growth of different decision trees can also be executed concurrently.

This experiment is mainly for the improved RF algorithm and the traditional RF algorithm in the student physical education teaching evaluation characteristic dataset test. The two algorithms were implemented on the spark cluster with three computing nodes, and the performance of the two algorithms was compared by using the time measurement method. The specific experimental results are shown in Table 6.

From Table 6 we can see that, after parallel processing, the improved RF algorithm has been shortened from 1486 seconds to 230 seconds, and the efficiency has been improved about 6 times. Due to the addition of simulated annealing algorithm for parameter optimization, the running time of the improved RF algorithm is longer than that of the traditional RF algorithm. In the single machine running process, the running time of the improved RF algorithm is almost three times longer than that of the traditional RF algorithm, but after data parallelization, the improved RF algorithm is only two times longer than the

Table 6: Running time comparison of the two algorithms.

	Parallelization run time (s)	Single machine running time (s)
Improved RF algorithm	230	1486
Traditional RF algorithm	132	528

traditional RF algorithm, which is mainly due to the parallel optimization of RF algorithm and simulated annealing algorithm.

5. Conclusion

The field of education is extremely important and has a significant influence on many civilizations. The evaluation of physical education teaching quality is one of the most important methods to improve the physical education teaching system. Keeping the significance of the physical education system in consideration various ML algorithms are used in this study to generate a high quality experienced and intelligent system that will improve the whole physical educational sector. The improved RF algorithm proposed in this study is simulated on the student achievement dataset. Through a number of experiments, it is confirmed that the simulated annealing algorithm, feature selection process, weight optimization, and other processes can provide assistance for the effectiveness of the algorithm. In addition, it can also identify the characteristic factors that have a significant impact on students' course performance and is helpful for the teaching curriculum reform. The improved RF algorithm is used in the evaluation of college physical education classroom and teaching quality, and through the mining and analysis of the survey data, it tries to find the factors that affect the quality of college physical education classroom teaching and provide scientific suggestions for future physical education classroom teaching reform. The future work of this study is to use more optimization and ML techniques to improve the accuracy of the student achievements and improve the physical education system.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Research Article

Realization of Mobile Education Resource Sharing Method Based on Wireless Broadband Connection

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Educational resource sharing among students is always an essential component for the development of education level. With the progress of digital and communication networks among institutions, the use and sharing of high-grade educational resources can reach a new level. This paper proposes a new platform for mobile educational resource prediction and sharing via wireless broadband access technology. The architecture of the resource sharing system comprises resource, management, and service layers. An evaluation index system is established to assess the quality of the resource, and a detailed description of the resource assessment methods is presented. Moreover, the social impacts on the allocation of resources and similarities between the social metrics such as response time, success rate, and resource acquisition were investigated. The system has the potential to provide a high success rate and low response time. The system proposed in the paper will stimulate teamwork between teaching groups and increase the ability of resource sharing and optimization more comprehensively.

1. Introduction

Recently, the demand for high-grade educational resources has been rapidly increasing worldwide, and the application of information technology has enabled the elevation of education and encouraged education revolution in numerous fields. However, the present methods of educational resource sharing are still at an initial stage. The most widely used method of educational resource sharing nowadays is an online education platform based on cloud computing, such as Coursera, Udemy, FutureLearn, Pluralsight, and Moodle [1]. These online platforms virtualize educational resources and systems and deploy them on the cloud platform which enables users all over the world to get access to such resources. Compared with conventional classroom learning, network distance learning provides incredible advantages with the richness of educational resources, sharing, interactivity, and teamwork of teaching activities [2]. Through these learning communities, resources can be shared, interactive communication can be carried out, and cooperative learning relationships can be established. Many communities show strong interaction, and the online Q&A of teachers and online communication of learners play a great role in promoting learning [3].

Mobile Notes is one example where technology is used in educational institutes to improve students' learning experience [4]. In this type of project, digital whiteboard and Personal Digital Assistant (PDA) devices are used by the pupils to provide data exchange and interaction. Educational information is shared in an asynchronous mode among the students through the use of a central database. Although a centralized asynchronous solution is beneficial for sharing educational information in several situations, these methods have a disadvantage that information is not shared instantly. Another educational resource project named Collpad [5] provides mobile-to-mobile communication for learning in an indoor environment. The system uses PDAs for communications for teachers and pupils and is based on WiFi connections in indoor environments. An educational resource sharing system based on combining several devices interfaces is presented in [6]. This system enables a user to combine several device interfaces and to connect seamlessly with one multidisplay device. The system employed a layered architecture and is confined to LAN as the communication channel. Didac et al. [7] proposed an education resource learning system comprised of aggregated mobile devices, forming organizations. These aggregated devices provide a new mechanism that facilitates the design of mobile learning activities offering a virtual complex device that combines the features of several mobile devices. Hou et al. [8] developed a method for educational resource sharing based on blockchain. The system was able to connect learners all over the world and provide access to high-quality educational resources. Moreover, the system has the potential to eliminate the trust barriers between higher educational institutions and social institutions and can well protect personal privacy. Yao and Xiong [9] proposed a cloud-based educational resource sharing model based on the analysis of related application status. The model comprises resources, service, and management layers. An assessment index was also constructed to evaluate the quality of the resource and the detailed description of the resource assessment methods. The model was effective to promote sharing of information resources and educational applications. Yalcin et al. [10] proposed a new model using virtualization technology for promoting educational materials using the computer network. The network topology consisted of real hardware instead of virtual ones, which distinguished it from similar topologies. This model can guide educational network and system managers to develop and use a real educational network and system management platform.

Conventional educational resource sharing methods use storage mode systems based on contents [11]. Data and information resources are stored on the storage server. If the server provides data for multiple users, a large-capacity hard drive will be required to store all types of educational resource files [12]. For colleges and universities, the recent growth of high-speed digital networks offers not only simple access to more efficient computing but also a new capability and an opportunity to access educational resources [13]. In this paper, a new algorithm is developed for mobile learning community resource sharing using broadband wireless connections. The system can provide high success rate and low response time while sharing educational resources among users. We also analyzed the impact of unequal distribution of resources on society and examined the similarity between response time and social indicators such as resource access.

The remaining sections of the paper are ordered as follows. Section 2 provides background and explains the architecture of the proposed education resource sharing system. The resource sharing algorithm is discussed in Section 3. In Section 4, the results are presented, and finally the conclusion is given in Section 5.

2. Theoretical Analysis

2.1. Social Network Analysis. Teacher communities are believed to contribute to improvements in the practices of teaching and research as well as to the collective capacity of educational institutions. The majority of teacher communities share educational resources in real-world environments and via online networks. Previous research shows that online networks may be an effective technique to promote collaboration and sharing of educational contents [14]. This study collected collaboration data from community members obtained through long-term experimental observation and recording. By examining the response time of members to acquire resources in the mobile learning community, recommendations that are more conducive to resource sharing can be made to promote the better development of the mobile learning community.

In the virtual learning community, the user relationship graph is formed by the friends between users [15]. After community division, there can be several subcommunities. The similarity between two users is calculated in the subcommunity, and the learning resources for the user's friends are calculated. Although learners in the virtual learning community form a social circle, there may be close and distant relationships among people in the social circle. People who have different number of friends in common have different chances of becoming friends, even if they are in the same social circle. Therefore, the affinity between learners can be obtained through similarity, thus generating a recommendation. In a mobile learning community, the learner can be connected on the cable to connect in the virtual community as well as through mobile devices using wireless or Bluetooth technology. For example, the function of WeChat is to look for someone near, so there is a high probability to become friends and share educational resources.

2.2. Network Centrality Analysis. Network centrality is a basic concept used to distinguish the status of community members in the network [16]. The higher the degree of centrality among individuals, the closer the relationship among the members of the community. If a member is directly related to a majority of the other members, then that member is a very important node in the process of community information transmission, playing a key role in interpersonal relationships, resource possession, and knowledge dissemination and sharing. On the contrary, if a member is in a marginal position in the network, he may acquire a lot of information, but he cannot play an important role in the transmission of information, and his position is not conducive to his contribution to the construction of group knowledge. The central potential is a quantification of the position of the local group in the community and represents the overall integration or consistency of the graph [17].

2.3. Network Density Analysis. Network density indicates the degree of interaction among the members of a community. A high density indicates more connections among members of a community, while a low density means fewer connections among members. The possible value of network density is between 0 and 1. If there is a direct relationship between each pair of members in the network community, the maximum value of network density is 1, but in most cases, the value of network density is less than 1 [18].

The network density is the ratio of the actual number of connections to the number of possible connections. Suppose that the interaction among the members of a community is represented by a directed graph "G"; then, the density "D" can be calculated as

$$D = \frac{n}{N(N-1)}, \quad (1)$$

where n is the number of actual connections and N is the number of actors. Density D shows the degree to which nodes are interconnected and can be used to measure the speed of information exchange.

2.4. Architecture of the Proposed Model. The overall architecture of the proposed intelligent distance education resource sharing platform is shown in Figure 1. The model comprises resource layer, management layer, and service layer. These layers are described in the following section [19].

(1) Service layer: this layer is mainly responsible for providing direct access to resource sharing services and is responsible for data storage. It also provides high storage capacity. This layer provides access to the shared resources using mobile phones, pads, computers, and other devices.

(2) Management layer: this layer is responsible for providing the system management functions, adopts cloud platform architecture, and simplifies the management process (by providing hardware equipment, storage, and operation management) and education managers to manage platform resources (including service, accounts, and resources). After applying for and obtaining a unified ID, each branch can access the resource pool and obtain corresponding services.

(3) Resource layer: in this layer, teaching resources and learning resources are summarized through unified interfaces. Sharing of teaching resources is realized through resource integration, and the unified storage of integrated teaching resources is used to effectively solve the problem of teaching resource management.

2.5. Information Storage. Distance education resource sharing platform based on cloud technology belongs to a large data center platform rather than a single commercial web server [18]. It consists of data center resources distributed in multiple regions and borrows a high-speed communication network as a platform. It combines all the control nodes of a university to the regional cloud data center to transmit teaching resources and realize the automatic transmission function of data among different cloud data centers. The central platform has the privileges to assign levels to users in provinces and cities. Combined with the addresses of accessing users, the data center is locked to further improve the data transmission efficiency. By modeling the resource sharing platform with

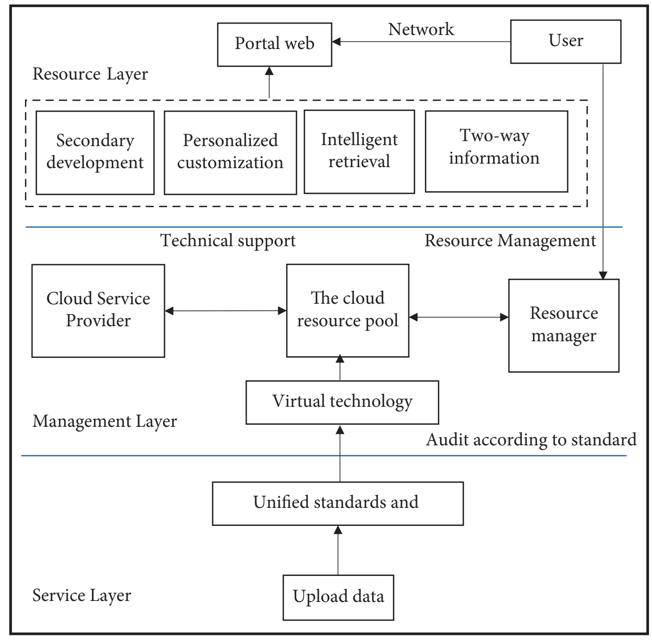

Figure 1: Platform architecture.

OpenStack toolsets, it can effectively manage a large number of resource pools (formed by computers, storage devices, and network resources). OpenStack is an open, free standard cloud computing platform. It is widely installed as infrastructure-as-a-service (IaaS) in both public and private clouds where resources and virtual servers are can be accessed by users [20]. The storage function architecture based on OpenStack is shown in Figure 2.

3. Mobile Learning Community Resource Sharing

In this study, the contact intensity between nodes was used to describe the similarity between nodes. Let $C_{(u,v)}$ represent the contact strength between node u and node v, and then the contact strength can be computed as

$$C_{(u,v)} = C_{(u,v)\text{old}} + \left(1 - C_{(u,v)\text{old}}\right) \times C_i, \quad (2)$$

where $C_{(u,v)\text{old}}$ represents the contact intensity between node u and node v in the last contact. C_i is an initial value, which was uniformly set to 0.75 in this experiment. The recession component was computed using the following equation:

$$C_{(u,v)} = C_{(u,v)\text{old}} \times \alpha^t, \quad (3)$$

where α is the decay index, which was set to 0.98 in this experiment.

The transmission component was computed as

$$C_{(u,\omega)} = C_{(u,\omega)\text{old}} + \left(1 - C_{(u,\omega)\text{old}}\right) \times C_{(u,\vartheta)} \times C_{(\vartheta,\omega)} \times \beta. \quad (4)$$

The parameter β is used to describe the dependence between nodes, which was set to 0.25 in the experiment.

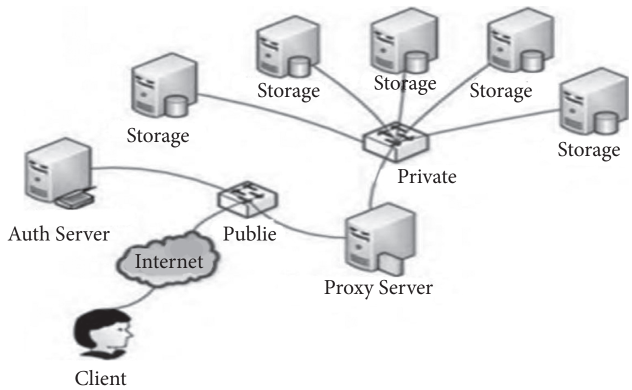

Figure 2: Storage architecture diagram.

The PageRank algorithm was used to calculate the centrality of nodes. Let $P_{(u)}$ represent the centrality of node u, and $P_{(u)}$ can be expressed as

$$P_{(u)} = \frac{1-d}{n} + d \sum_{\vartheta \varepsilon N(u)} \frac{P_{(\vartheta)}}{N_{(\vartheta)}}, \quad (5)$$

where the parameter d represents the decay factor, which was set to 0.3 in the current experiment, and $N_{(u)}$ represents the number of neighbors of node u.

According to the weighted square Euclidean distance measure between the sample and the cluster center, the objective function is minimized and the membership degree and cluster center are obtained. The clustering objective function was described as follows:

$$\min L_m = \sum_{i=1}^{N} \sum_{j=1}^{K} z_{ij}^{m} \left\| x_i - V_j \right\|^2. \quad (6)$$

Furthermore, the fuzzy membership and dissimilarity measure was employed to construct the objective function, find the minimum membership and cluster center of the objective function through iteration, and realize sample classification.

$$J = \sum_{i=1}^{N} \sum_{j=1}^{K} u_{ij}^{m} \left[d^2\left(x_i, v_j\right) + G_{ij} \right],$$
$$G_{ij} = \sum_{\beta = N_I} \frac{1}{d_{i\beta} + 1} \left(1 - u_{i\beta}\right)^m. \quad (7)$$

Finally, the optimization solution expression of the objective function was computed as

$$u_{ij} = \frac{1}{\sum_{l=1}^{K} d^2\left(x_i, v_j\right) + G_{ij}/d^2\left(x_i, v_l\right) + G_{il}},$$
$$v_k = \frac{\sum_{j=1}^{K} u_{ij}^{m} x_i}{\sum_{j=1}^{K} u_{ij}^{m}}. \quad (8)$$

3.1. Proposed Algorithm. Considering the self-organization characteristics in the person-to-person contact environment, a distributed node centrality algorithm is proposed in this study. When two nodes meet, they exchange their current centrality information and the number of neighbors (Algorithm 1: steps 5 and 6) and then update their centrality (Step 7) according to steps given in equation (5). The whole calculation process is described in Algorithm 1.

4. Experimental Process and Performance Analysis

4.1. Setting Up the Experimental Environment. In this study, a simulation platform based on VC.NET is developed. The whole platform integrates the common node movement model, resource query, sharing algorithm, and neighbor discovery. The overall interface of the system is mainly composed of the initial set of the system environment, the choice of node movement mode, and the algorithm of resource sharing. The settings of environment variables used in this system mainly include the realization of environment area, number of nodes, maximum communication distance of nodes, size of node buffer, neighborhood identification cycle, packet sending rate, and experiment duration. The simulation platform integrates three of the most representative movement models and a real dataset collected at the Korean Advanced Institute of Science and Technology (KAIST).

We employed a dataset provided by the Korean Academy of Sciences [11]. The dataset collected the movement tracks of 34 students over a period of nearly two years, generating a total of 92 files, each containing hundreds to thousands of independent system logs. This dataset contains information about the location of each student at different times. The specific format of data in each file is as follows: residence time, location (x, y), where x and y represent the coordinate information of each student.

4.2. Experimental Performance Analysis. In this section, we analyzed the influence of user's sociality on the efficiency of the proposed educational resource sharing model. We investigated the influence of user similarity and centrality on the response time of the resource acquisition model. The resource acquisition response time refers to the time between a user making a request for a particular educational resource and the user receiving the resource. The resource response time of the system is represented by the average of the resource response times of all the users.

We first analyze the types and number of educational resources that are known to the users, that is, the users in the system know exactly what resources other users have. In this case, when a user initiates a resource sharing request message, the user receiving the message responds with a confirmation message if it has the resource available. If the resource is not available with the current user, the node forwards the request message to those nodes that are closely related to the resource owner (i.e., those nodes that are highly similar to the resource owner). When the other nodes receive the same request message, they operate similarly. To study the impact of node similarity on resource response time, we devise another strategy for comparative analysis: we

Step Action
(1) Assume that $N_{(u)} \geq 0$
(2) $P_{(u)} = 0$
(3) While node u encounters node ϑ
(4) If ϑ is the neighbor of u
(5) Send $(N_{(\vartheta)}, P_{(\vartheta)})$
(6) Receive $(N_{(\vartheta)}, P_{(\vartheta)})$
(7) Update $(P_{(u)})$
(8) Endif
(9) End while

ALGORITHM 1: Node centrality.

randomly select K nodes as relays. Finally, the response time of the resources in these two cases is calculated.

4.2.1. Average Response Time. Figure 3 shows the average response time when $K = 8$. It is evident that the response time gradually gets longer with the progress of the experiment. The brown-colored line bars in the figure represent the time it takes for learners to obtain resources (k nodes are randomly selected as relays) after making resource requests in the learning group under normal circumstances. The blue bars indicate the response time of the resource when the request information is forwarded to members who are more similar to the resource owner. It can be seen that the time required to seek help from members with high similarity is 70% lower than the time required for normal communication (this is particularly obvious in 1200 s).

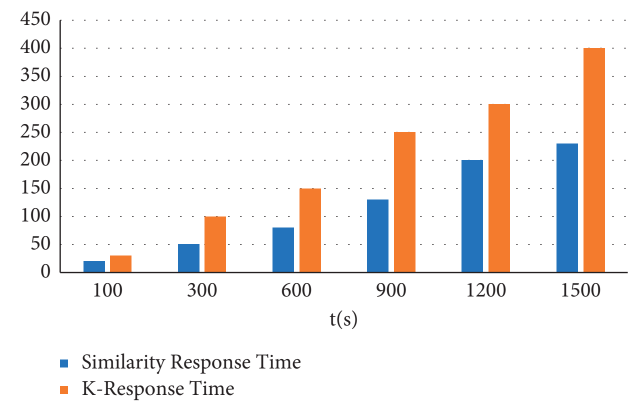

FIGURE 3: Average response time.

4.2.2. Success Rate. Figure 4 shows the success rate of resource requests in both cases. It can be seen that the success rate of resource requests of nodes with high similarity is also higher than the success rate of resource acquisition by randomly selected nodes. For example, the success rate of high similarity response time is 0.8 as compared to the success rate of success rate with random k point selection. Therefore, in the mobile learning community, when members know which members can help them or their friends are likely to help them, they can make requests directly to them, and it is a very convenient method to get resources.

The above analysis assumes that learners who have resources are known, and then they request these members to analyze their response time and success rate of obtaining resources. However, in most cases, learners may not know which nodes have resources, and in fact, there is no need to care about the owners of resources. Users care about access to the resource, not where it is stored. In this case, K nodes with high centrality are selected to participate in resource request forwarding, that is, the resource requesting node sends the request information to the nodes with high centrality, and these nodes carry out the relay operation.

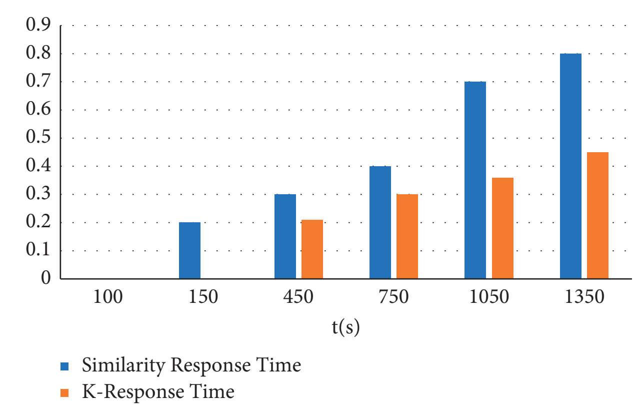

FIGURE 4: Comparison of similarity and success rate of randomly selected resource requests.

4.2.3. Effect of Node Selection. Figure 5 shows the success rate for different values of k. It can be seen that the success rates gradually decrease when the value of k is increased from 3 to 30 in the experiment. The results show that the method of K-node selection is adversely affected when the number of nodes for K-node selection increased as opposed to the proposed method. This validates that the method of high similarity is more superior to the method of K-node selection for educational resource sharing.

Based on the above experimental results, it can be concluded that in the learning community established in the WiFi environment, the shortest response time of interaction between members is 300 s, and the average time is about 13 min, which is acceptable. In addition, today's smartphones also provide a mobile push

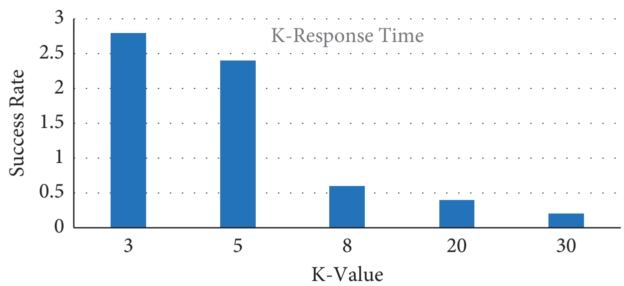

Figure 5: Effects of node selection.

notification function. For example, using WeChat, mobile QQ, and other software as the learning environment, the response time will be shorter, and community members can receive requests and reply in time. In this community, if learners ask questions to members with high centrality, the success rate of resource acquisition will be higher and the response time will be shorter. This is also related to the active degree of each member in the learning community. The higher the active degree is, the faster the corresponding help will be received, the shorter the response time is, and the longer the survival time of the community is.

5. Conclusion

In this study, an educational resource sharing algorithm based on WiFi is presented. Based on the analysis of the current teaching resource sharing system and its characteristics, an educational resource sharing system based on the service mode of the teaching sharing platform is designed. The system has a high success rate and low response time. The results show that in an environment where the resource owner is known, sending the resource request information to users with high similarity to the resource owner will reduce the response time of the resource and improve the success rate of the resource request. In an environment where the owner of the resource is unknown, sending the resource request information to those nodes will significantly reduce the efficiency of resource sharing. Encourage regional teaching units to provide broader collaboration and more comprehensive resource sharing.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Dynamic Facial Expression Recognition Using Sparse Reserved Projection Algorithm for Low Illumination Images

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In this paper, a novel approach for facial expression recognition based on sparse retained projection is proposed. The locality preserving projection (LPP) algorithm is used to reduce the dimension of face image data that ensures the local near-neighbor relationship of face images. The sparse representation method is used to solve the partial occlusion of human face and the problem of light imbalance. Through sparse reconstruction, the sparse reconstruction information of expression is retained as well as the local neighborhood information of expression, which can extract more effective and judgmental internal features from the original expression data, and the obtained projection is relatively stable. The recognition results based on CK + expression database show that this method can effectively improve the facial expression recognition rate.

1. Introduction

As an important branch of pattern recognition research, face recognition technology has become a research hotspot in today's society. Face recognition technology is realized via the face image analysis and extraction of image characteristic data, such as those with the most discriminating information to identify a technology [1]. The current face recognition technology is based on a single image and image set recognition methods. In single image recognition, each image acts on behalf of a sample, whereas in the image set recognition method, a person's multiple images are used to represent a sample that constitutes an image set. Face recognition technology involves many fields such as cognitive psychology, image processing, pattern recognition, computer vision, and physiology, so there are a lot of researchers involved in face recognition research, which means face recognition technology has seen rapid development [2].

Although face recognition technology has been applied in real life, the current technology has not fully reached the mature state, and it still faces many difficulties and challenges. In practical applications, the face may be affected by some natural conditions, such as the impact of light imbalance, partial shielding of the face, facial expression change, posture change, age, and many other noises, which can affect the accuracy of face recognition results. Therefore, the current research focus should be on solving these key problems that hinder the development of face recognition technology. With the attention of researchers on face recognition worldwide, face recognition technology has made great achievements. In China, the team led by researcher Shan Shiguang, as well as the team led by Professor Gao Wen and Professor Chen Xilin, made significant contributions on face recognition and detection, and they established a large-scale domestic face database and many face recognition algorithms [3]. The team led by Professors Xu Guangyou and Zhang Changshui has made significant achievements by conducting an in-depth study of face pose changes in the process of face recognition [4]. The team led by Professor Yang Jingyu has been engaged in face recognition research for a long time. The main research direction is to analyze the algebraic features of face images and propose a variety of new face recognition algorithms [5]. In addition to the research teams listed above, there are many other research teams that have been engaged in face recognition-related research for a long time and have made corresponding achievements and progress [6, 7].

The experimental face library used by authors in [8] contained sample images of 16 people, of which each person had 9 images of faces with different shooting angles, lighting conditions, and different sizes. All the images of each person showed no significant change in expression. The recognition rate can reach up to 96% under different lighting conditions, 64% for face images of different scales, and 85% for face images of different angles. The authors in [9] proposed a method based on elastic graph matching with relatively high recognition rate, which is a method of feature information extraction based on dynamic link structure. They represented the face image as a graph structure, and the nodes of the graph were some key points in the face image (such as nose, mouth, and eyes). The links to these key information points form the edges of the graph, where each node contains a number of key information that is used to form the template of the face image. In [10], the authors used a neural network approach for face recognition. They first extracted 50 key feature information from face images and then mapped that information to the five-dimensional network space through the neural network and finally recognized and classified face images through the multilayer perception system (MLP) of the neural network. Through the continuous improvement and innovation of researchers, a variety of neural network structures have been proposed successively, and the recognition rate of face images has been improved to varying degrees.

In this paper, numerous challenges encountered in the process of face recognition were studied and analyzed. Using locality preserving projection (LPP) algorithm and sparse representation method, we found that LPP algorithm used for reducing the dimension of face image can ensure the local near-neighbor relationship of face image data. This makes the neighborhood relationship between the image samples before and after dimensionality reduction to be maintained and preserved. In addition, sparse representation can well solve partial occlusion and illumination imbalance [11], and it has strong robustness to these problems. Therefore, sparse representation was used to classify the data after dimensionality reduction. Therefore, in this paper, we combine the LPP with the classification method of sparse representation, effectively solving the impact of relevant problems on the recognition process and achieving a good recognition rate.

The rest of this paper is organized as follows. In Section 2, the local retained projection algorithm is discussed, which is based on the sparse classification. In Section 3, the proposed face dynamic expression recognition method for low illumination image is discussed. In Section 4, the experimental results are provided. Finally, the paper is concluded and future research directions are provided in Section 5.

2. Local Retained Projection Algorithm Based on Sparse Classification

In this section, first the LPP algorithm used by the proposed scheme is discussed. Next, the sparse representation classification is discussed. Both these approaches are the main approaches used by dynamic facial expression recognition techniques for low illumination images.

2.1. Locality Preserving Projection (LPP) Algorithm. Locality preserving projection (LPP) algorithm [12] is an unsupervised dimensionality reduction algorithm, which mainly aims at dimensionality reduction of nonlinear data. Its characteristic is that it can maintain the original topological structure relationship of the data points of the sample. It projects the data from the high-dimensional manifold space to the low-dimensional space by finding a projection matrix, aiming at finding the low-dimensional linear space embedded in the high-dimensional manifold space. The LPP algorithm ensures that the original local neighbor relationship can still be maintained after dimensionality reduction by constructing the neighbor graph.

The general process of linear dimension reduction can be described as follows: For R^m given sample set $X = \{x_1, x_2, \ldots, x_k\}$ of k data in the high-dimensional space, we need to find a projection matrix A to map all the data in the high-dimensional space to a low-dimensional space R^l, where $l \ll m$, and obtain the sample point set $Y = \{y_1, y_2, \ldots, y_k\}$ corresponding to all k samples in the low-dimensional space, and we can get $y_i = Ax_i$. In this way, for each x_i, y_i can be found to make a good low-dimensional representation of it, so as to achieve the purpose of dimensionality reduction. The LPP algorithm assumes that the high-dimensional data $X = \{x_1, x_2, \ldots, x_k\}$ are embedded on the manifold plane M in the high-dimensional spaceR^m.

2.1.1. Building the Nearest Neighbor Graph. LPP algorithm is the first step to build a neighbor graph G using $X = \{x_1, x_2, \ldots, x_k\}$. Consider a set of adjacent G samples, each sample point is one of the vertices; a total of k vertices, for two vertices x_i and x_j if they are as close neighbors, are connected by edges x_i and x_j, otherwise there is no boundary between x_i and x_j, to judge whether x_i and x_j are the neighbors. The relationship between them uses the following two methods:

(a) ε-domain method: by setting a threshold ε, for each sample of data x_i, calculate the Euclidian distance between it and all other samples. If $x_j \|x_i - x_j\|^2 < \varepsilon$, the sample points x_i and x_j are considered to be close neighbors, and an edge link is used between them; otherwise, they are considered to be nonclose neighbors;

(b) K-nearest neighbor method: for each data sample x_i, calculate the Euclidean distance between it and all other samples. Select the first k sample points with the smallest Euclidean distance to x_i as the nearest sample points to x_i and link them with an edge, respectively. Figure 1 vividly shows the two methods of finding the nearest sample points.

2.1.2. Determining the Weights of a Graph. After the construction of the nearest neighbor graph in the first step, it is necessary to assign a weight to the edge of the nearest neighbor graph to construct the weight matrix W. This weight reflects the degree of similarity between nearby samples. The greater the weight, the higher the similarity

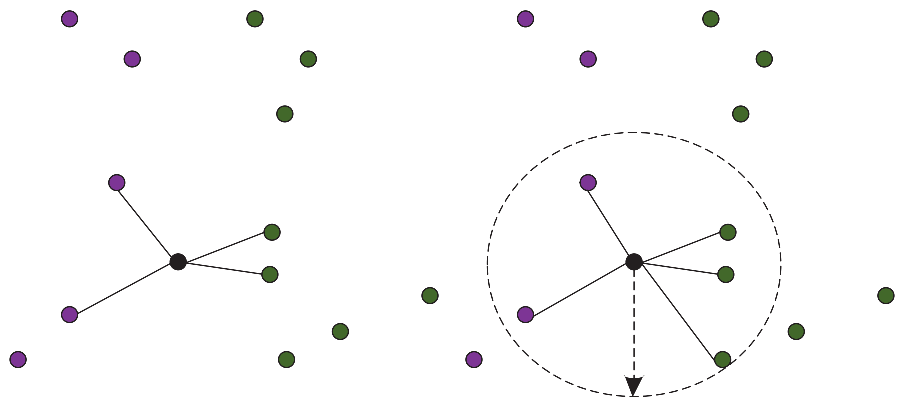


Figure 1: (a) k-neighborhood graph vs. (b) epsilon-neighborhood graph.

between samples. There are two methods for weight calculation:

(a) Thermonuclear-based methods:

$$W_{ij} = \begin{cases} e^{-\|x_i - x_j\|^2/t}, & \text{if } x_i \text{ and } x_j \text{ are adjacent,} \\ 0, & \text{if } x_i \text{ and } x_j \text{ are not adjacent.} \end{cases} \quad (1)$$

(b) Method based on the 0-1 principle:

$$W_{ij} = \begin{cases} 1, & \text{if } x_i \text{ and } x_j \text{ are adjacent,} \\ 0, & \text{if } x_i \text{ and } x_j \text{ are not adjacent.} \end{cases} \quad (2)$$

2.1.3. The Target Code. The goal of the LPP algorithm is to find a projection matrix A to project data from the high-dimensional space to the low-dimensional space. The LPP algorithm obtains the projection matrix A by minimizing the following objective function:

$$\sum_{i,j} \left(y_i - y_j\right)^2 W_{ij}, \quad (3)$$

where y_i and y_j are data sample points of dimensionality reduction and can be obtained by sorting out the above equation:

$$\begin{aligned} \frac{1}{2}\sum_{i,j}\left(y_i - y_j\right)^2 W_{ij} &= \frac{1}{2}\sum_{i,j}\left(A^T y_i - A^T y_j\right)^2 W_{ij} \\ &= \sum_{i,j} A^T x_i D_{ii} x_i^T A \\ &\quad - \sum_{i,j} A^T x_i W_{ii} x_i^T A = A^T X (D - S) X^T A \\ &= A^T X L X^T A, \end{aligned} \quad (4)$$

where $D_{ii} = \sum_{i,j} W_{ij}$ and $L = D - W$ are known as Laplacian matrices. In order to eliminate the arbitrariness and scaling of the above minimization problem, a restriction condition is added to the above minimization problem:

$$\sum_i D_{ii} y_j^2 = 1 \Rightarrow A^T X L X^T A - 1. \quad (5)$$

With this constraint added, the above minimization problem is relatively simple and can be transformed into the minimization problem with the following constraints:

$$\arg \min_{A^T \mathrm{XDX}^T A = 1} A^T \mathrm{XLX}^T A. \quad (6)$$

The solution of this objective function can be regarded as the eigenvector problem of solving a generalized characteristic equation:

$$\mathrm{XLX}^T a = \lambda \mathrm{XDX}^T a. \quad (7)$$

Calculate all eigenvalues and eigenvectors corresponding to formula (7) and sort the eigenvalues from small to large. K eigenvalues can be obtained: $\lambda_0 < \lambda_1 < \cdots < \lambda_{k-1}$, and the eigenvector corresponding to it is $a_0, a_1, \ldots, a_{k-1}$. Take the first eigenvector to form a projection matrix $A = [a_0, a_1, \ldots, a_l]$, then

$$x_i \longrightarrow y_i = A^T x_i, \quad (8)$$

where y_j is an l-dimensional vector, which is an $m \times l$ matrix.

2.2. Sparse Representation Classification. The classification method is based on the degree of sparseness. All training samples form a data dictionary. The dictionary in each column represents a face image. Then for a new test sample, all training samples can be used to delinearize. In data analysis, the sparse coefficient vector is obtained according to the data dictionary.

2.2.1. Sparse Representation of Test Samples. Firstly, it is assumed that there are n_i face images for the training samples of class i, and each face image is represented by an m-dimensional column vector v. Then, all face samples of class i can be expressed as follows:

$A_i = [v_{i,1}, v_{i,2}, \ldots, v_{i,n}] \in R^{m\times n_i}$, where n_i represents the number of face samples contained in class i and $v_{i,j}$ represents the j face sample of the ith individual. Then, for a new test sample y of class i, it can be linear, represented by all the training face samples of i, so y can be expressed as the following linear combination:

$$y = a_{i,1}v_{i,1} + a_{i,2}v_{i,2} + \cdots + a_{i,n_i}v_{i,n_i} \in R^m. \quad (9)$$

Here, $a_{i,j} \in R(1, 2, \ldots, n_i)$ is the coefficient of a linear combination. It is assumed that y belongs to class i, because in the actual classification and recognition process, it is unknown which class y belongs to. Therefore, for all k categories (class i contains n_i training sample), a total of n training samples can be formed into a large dictionary matrix as follows:

$$A = [A_1, \ldots, A_i, A_k] = \left[v_{1,1}, v_{1,2}, \ldots, v_{1,n_1}, \ldots, v_{i,n_i}, \ldots, v_{k,1}, v_{k,2}, \ldots, v_{k,n_k}\right] \in R^{m\times n}. \quad (10)$$

Then, for any test sample y, all n training samples can be used to make a linear representation of it, that is, it can be expressed in a linear combination:

$$y = Ax \in R^m, \quad (11)$$

where x is a sparse coefficient vector. If y is a sample of class i, then a sparse coefficient vector $x = [0, 0, \ldots, 0, a_{i,1}, a_{i,2}, a_{i,n_i}, 0, 0, \ldots, 0] \in R^m$ can be obtained under ideal circumstances. It can be seen from the coefficient vector that only the coefficients corresponding to the samples belonging to the same class with y are not zero, and the other samples are all equal to zero. So, sparse coefficient vector x retained information about classes, so we can pass the sparse coefficient vectors to order a test sample y category information.

(i) Solving Sparse Solution. In the process of sparse representation, the most important problem is to solve the sparse coefficient vector x. In the practical application, we hope to find a coefficient vector x that is sparse enough and can fully represent the test sample y. For the solution of x, we can solve it by l^2 norm:

$$\begin{aligned} &\hat{x}_2, \arg\min \|x\|_2, \\ &s.t., Ax. \end{aligned} \quad (12)$$

The norm problem is easy to solve by taking the pseudoinverse of the matrix A and then solving for $\hat{x}_2$. However, the vector $\hat{x}_2$ obtained by l^2 norm is not easy to test samples for classification, and the solutions obtained by it are usually relatively dense, that is, the nonzero terms in vector $\hat{x}_2$ correspond to a large number of categories, which leads to increased difficulty in classification. In order to solve the dense problem, the coefficient vector can be more strictly restricted, so the norm l^0 is used to solve:

$$\begin{aligned} \hat{x}_0 &= \arg\min \|x\|_0, \\ s.t. \quad y &= Ax. \end{aligned} \quad (13)$$

The relatively sparse coefficient vector $\hat{x}_0$ can be obtained by solving the optimal solution of norm l^0 above. However, the solution of norm l^0 optimization problem has always been an NP-hard problem, and there is a problem that the solution is not unique, so its solution is not as simple as the l^2 norm. Therefore, the l^0 norm optimization solution is also not good. Finally, a compromise method is adopted to solve the problem through the l^1 norm. Through the l^i norm, relatively sparse coefficient vectors can be obtained, and in general, there is a unique solution:

$$\begin{aligned} \hat{x}_1 &= \arg\min \|x\|_1, \\ s.t. \quad y &= Ax. \end{aligned} \quad (14)$$

The desired sparse representation $\hat{x}_1$ can be obtained through the optimization solution of l^1 norm, and the following sample classification and recognition can be carried out through this coefficient vector.

(ii) Classification Based on Sparse Representation. In an ideal case, the nonzero term in the solved sparse coefficient vector $\hat{x}_1$ is the coefficient corresponding to the samples of the same class of the test sample, and the coefficient term corresponding to other samples that do not belong to the same class of the test sample is zero. Since the coefficient reflects the similarity between samples, the classification and recognition of test samples can be carried out according to the sparse coefficient vector. Samples corresponding to the term with the largest coefficient in the vector can be selected and then the test samples can be classified into the same category. In this way, classification and recognition can be realized. However, in practical applications, due to the existence of noise and model error, the situation is often not so ideal, and the nonzero term in the coefficient vector obtained is not necessarily the same category as the test sample. Therefore, the method with the largest coefficient cannot be simply selected for the classification of test samples.

For better classification, recognition, and accurate results, the concept of residual error (reconstruction error) is introduced for the sparse classification. The category to which y belongs is judged by calculating the reconstruction error of the test sample of each class. The class with the smallest reconstruction error value is regarded as the category to which y belongs. For this purpose, the following classification criterion function is used:

$$\min r_i(y) = \left\| y - A\delta_i(x) \right\|_{2,} \quad (15)$$

where $r_i(y) \in R$ is the reconstruction error of test sample y on class i; $\delta_i(x) \in R^n$ is a new sparse coefficient vector. It only keeps the coefficient corresponding to the item of class i

training samples in the sparse coefficient vector $\hat{x}_1$ and sets all other coefficients to zero. In this case, it is the reconstruction and recovery of test sample y on the class i. By calculating the sum of the square of the difference between the test sample y and its reconstruction recovery sample $\hat{y}_i = A\delta_i(x) \in R^m$ on class i, the reconstruction error on class i can be obtained.

3. Face Dynamic Expression Recognition Method for Low Illumination Image

First the face detection approach using AdaBoost algorithm is discussed in Section 3.1 followed by expression feature extraction based on sparse reserved projection algorithm in Section 3.2.

3.1. Face Detection Based on AdaBoost Algorithm. The face detection algorithm based on AdaBoost algorithm consists of three parts: Haar-like feature representation, strong classifier construction, and cascade structure processing [13]. Its detection flow chart is shown in Figure 2.

3.1.1. Haar-Like Features. There are four basic feature templates of Haar-like features, as shown in Figure 3. The template is composed of black and white rectangles, and the eigenvalue is expressed as the difference of the sum of pixels between the two rectangles. A template represents a child window used to extract local features of the face.

In Figure 3, the characteristics of class (a), (b), and (d) and the eigenvalue V are

$$v = \mathrm{Sum}_{\mathrm{white}} - \mathrm{Sum}_{\mathrm{black}}. \tag{16}$$

For the features of class (c), if the number of pixels of the black and white rectangle is the same, the calculation formula of its eigenvalue is as follows:

$$v = \mathrm{Sum}_{\mathrm{white}} - 2\mathrm{Sum}_{\mathrm{black}}. \tag{17}$$

In order to speed up the calculation speed, the face detection method based on AdaBoost algorithm calculates Haar-like eigenvalue by using integral image [14]. Save the pixel sum of the rectangle in the array to reduce duplicate operations. The integral of image I at point (x, y) and image II (x, y) is defined as

$$\mathrm{II}(x, y) = \sum_{x' \le x} \sum_{x' \le x} \mathrm{I}(x', y'), \tag{18}$$

where I (x', y') is the pixel value of image I at point (x', y'). Calculation of integral image is shown in Figure 4.

As shown in Figure 4, the integral image of each point is as follows:

$$\begin{cases} \mathrm{II}_1 = \mathrm{Sum}(A), \\ \mathrm{II}_2 = \mathrm{Sum}(A) + \mathrm{Sum}(B), \\ \mathrm{II}_3 = \mathrm{Sum}(A) + \mathrm{Sum}(C), \\ \mathrm{II}_4 = \mathrm{Sum}(A) + \mathrm{Sum}(B) + \mathrm{Sum}(C) + \mathrm{Sum}(D). \end{cases} \tag{19}$$

Then, the sum of pixels of rectangle D is

$$\mathrm{Sum}(D) = \mathrm{II}_1 + \mathrm{II}_4 - (\mathrm{II}_2 + \mathrm{II}_3). \tag{20}$$

It can be seen that the Haar-like eigenvalue only needs to calculate the integral image of the rectangular endpoint, which greatly reduces the calculation amount and improves the efficiency of feature extraction.

3.1.2. Strong Classifier Construction. AdaBoost is an adaptive iterative algorithm [15]. Its basic principle is to combine multiple weak classifiers into strong classifiers. The expression for constructing the weak classifier $h_j(x)$ is as follows:

$$h_j(x) = \begin{cases} 1, & p_j f_j(x), \\ 0, & \text{otherwise}. \end{cases} \tag{21}$$

In equation (21), $f_j(x)$ represents the eigenvalue of the subwindow to be measured in the image corresponding to feature j, θ_j represents the threshold of the weak classifier, and P_j represents the direction of the inequality sign. If the positive sample is classified below θ_j, then $P_j = 1$; otherwise, $P_j = -1$.

The steps to build strong classifier $H(x)$ are as follows:

Step 1: given the training sample set $\{(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)\}$, $y_i = 1$ represents the positive sample and $y_i = 0$ represents the negative sample.

Step 2: initialize the weight of sample x_i according to equation (21):

$$w_{1/j} = \begin{cases} \dfrac{1}{2l}, & \text{if } x_i \text{ is a positive sample}, \\ \\ \dfrac{1}{2m}, & \text{if } x_i \text{ is a negative sample}. \end{cases} \tag{22}$$

In equation (22), $\boldsymbol{l}$ is the number of positive samples and m is the number of negative samples.

3.1.3. Facial Detection Based on AdaBoost Algorithm. The last step of the method is to process the cascade structure of the generated strong classifier $H(x)$, as shown in Figure 5.

The cascading processing structure of strong classifier reflects two advantages of AdaBoost algorithm:

(1) The classifier located at the front end of the cascade structure can quickly exclude the subwindows that do not belong to the facial region. If the input image subwindow is denied once, it cannot enter the next level of classifier, thereby reducing the amount of computation.

(2) The results are more accurate because the input image subwindow is filtered layer-by-layer, only each classifier in the cascade structure is judged to belong to the face region and can finally be detected as a face.

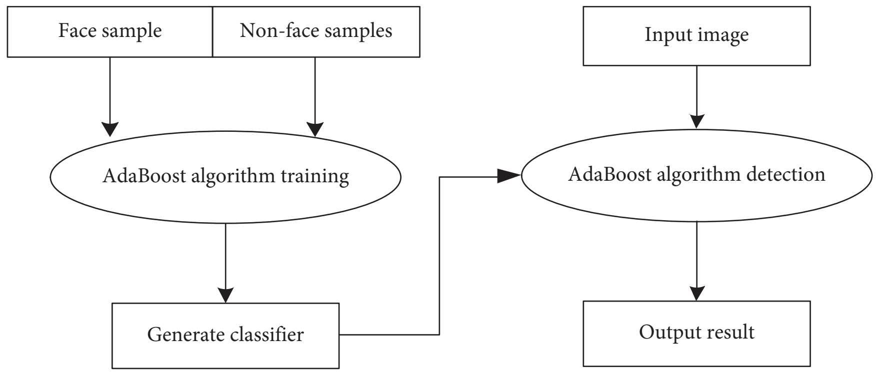


Figure 2: Flow chart of facial detection based on AdaBoost algorithm.

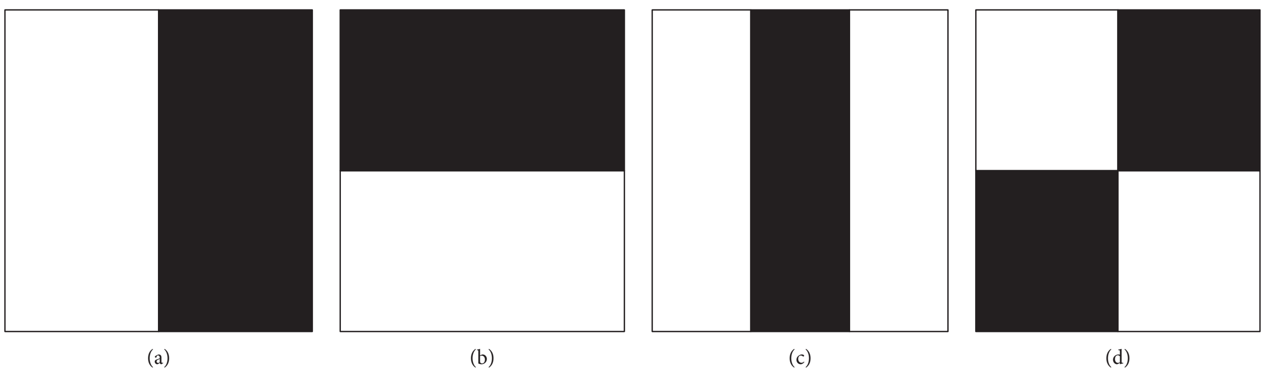


Figure 3: Haar-like feature template. (a) Feature template 1, (b) feature template 2, (c) feature template 3, and (d) feature template 4.

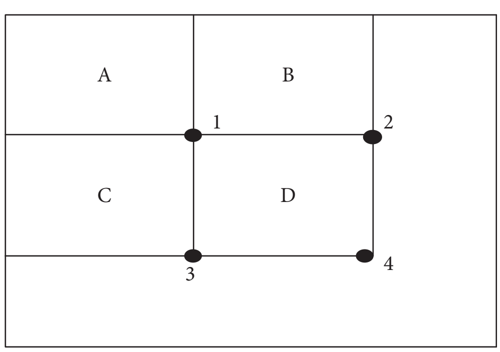


Figure 4: Calculation of integral image.

3.2. Expression Feature Extraction Based on Sparse Reserved Projection Algorithm. In the traditional facial expression recognition system, the expression feature extraction module is the core module, and the effective feature extraction directly affects the final recognition result. Facial expressions are rich in features, so there are many methods for feature extraction. This paper mainly uses LBP feature extraction. Local binary pattern (LBP) is a texture feature descriptor commonly used in image processing. Its remarkable feature is that it not only extracts image features effectively but also ensures a small amount of computation. The standard LBP operator contains the gray value of 9 pixels, and its structure is shown in Figure 6.

In Figure 6, g_c is the gray value of the center pixel of the window, which is defined as the threshold value. LBP operator feature extraction can be divided into three steps.

Step 1. Compare the 8 gray values $g_0, g_1, \ldots, g_7$ adjacent to the threshold with themselves in turn. If g_i is greater than the threshold, then the position of the pixel corresponding to the gray value is marked as 1; if g_i is less than the threshold value, the position of the corresponding pixel value is marked as 0. Thus, a 3×3 window can generate 8 binaries.

Step 2. Arrange the 8 binary codes generated in Step 1 in sequence to obtain a string of 8-bit binary numbers, namely, the LBP binary code of the pixel in the center of the window.

Step 3. Convert the LBP binary code obtained in Step 2 into decimal number to obtain the LBP value of the pixel in the center of the window.

Although the standard LBP operator can extract the image texture features effectively, its coverage is small and there are some defects. The extended LBP operator and the uniform mode LBP operator evolved from the standard LBP operator, and these two operators have stronger expression ability.

Extended LBP operator is an enhancement of the standard LBP operator, which expands the 3×3 window neighborhood to any scale. The structure of the extended LBP operator is shown in Figure 7. P and RLBP are used to

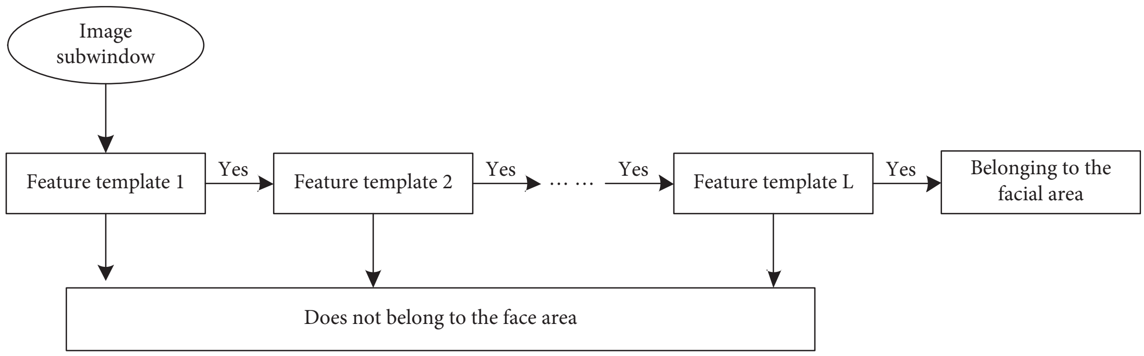


Figure 5: Schematic diagram of cascade structure.

represent the LBP value of the center pixel in the circular neighborhood, where P represents the number of sampling points and R represents the radius of the circular neighborhood. Then, the texture information of the three circular neighborhoods in Figure 7 is respectively represented as $LBP_{4,1}$, $LBP_{8,1}$, and $LBP_{8,2}$.

Let the coordinate of the central pixel be (x_c, y_c) and the coordinate of the sampling point in the circular neighborhood be (x_p, y_p), then

$$\begin{cases} x_p = x_c + R\cos\left(\dfrac{2\pi p}{P}\right), \\ y_p = y_c + R\sin\left(\dfrac{2\pi p}{P}\right). \end{cases} \tag{23}$$

In order to describe the texture information of the circular neighborhood conveniently, an auxiliary function $s(x)$ is defined as follows:

$$s(x) = \begin{cases} 1, & x \geq 0, \\ 0, & x < 0. \end{cases} \tag{24}$$

By referring to the calculation method of the standard LBP operator, the LBP value of (x_c, y_c) is

$$LBP_{P,R} = \sum_{P=0}^{P-1} s\left(g_p - g_c\right) \times 2^P. \tag{25}$$

In equation (25), $g_p\,(p = 0, 1, \ldots, P-1)$ represents the gray value of P sampling points around $(x_c, y_c)B$.

4. Experiment Results

In this section, first the parameter settings are discussed followed by results and analysis.

4.1. Parameter Settings. The parameters of the VGG-19 pretraining model were transferred to the facial expression recognition network model by transfer learning method, and the facial expression recognition network model was trained by locality preserving projection (LPP) algorithm. Freeze the parameters of the first 12 convolution layers and train and optimize the last 4 convolution layers, 2 full connection layers, and the new Softmax classification layer. The batch size is set to 48, the initial learning rate is set to 0.005, and the number of training periods epoch is set to 100, respectively.

4.2. Results and Analysis. In order to verify the effectiveness of the method presented in this paper, the expression recognition method based on sparse reserved projection algorithm and the algorithm based on Yang et al. [5] and Zhuang and Ding [6] are respectively used to carry out comparative experiments. From here onward, I refer to them as reference [5] and reference [6] respectively for the ease of understanding.

Figure 8 shows the changes of the loss function values of the two models on CK + expression datasets. It can be seen that, in the process of model learning, the network convergence speed of the algorithm in reference [5] and reference [6] is slow, and the loss function value drops to 0.8 and 0.9, respectively. It shows that the model learning ability of the method in this paper is stronger.

Table 1 shows the confusion matrices of the three models under CK + expression datasets. The recognition rates of the algorithm in reference [5] and reference [6] are 91.17% and 89.25%, respectively, while the recognition rate of the method in this paper is 94.12%. It can be seen that the sparse retained projection algorithm is used in the experiment to achieve a higher recognition rate than other deep learning methods. The proposed method achieves a high recognition rate on the dataset, which shows the rationality and effectiveness of the proposed model.

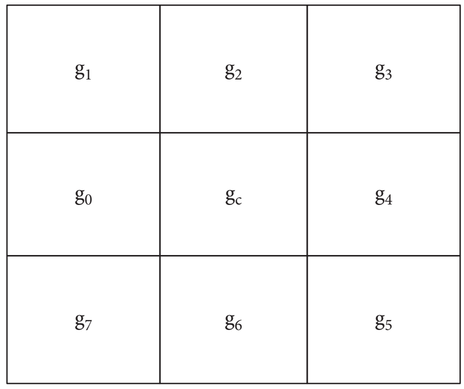
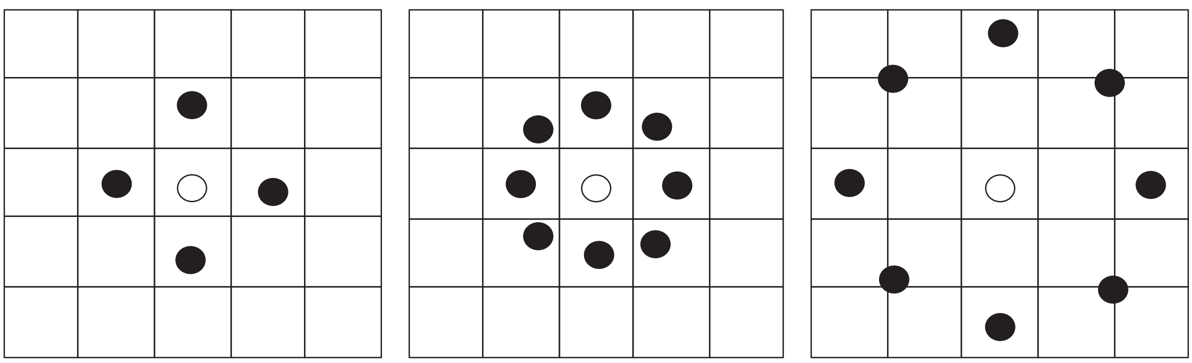
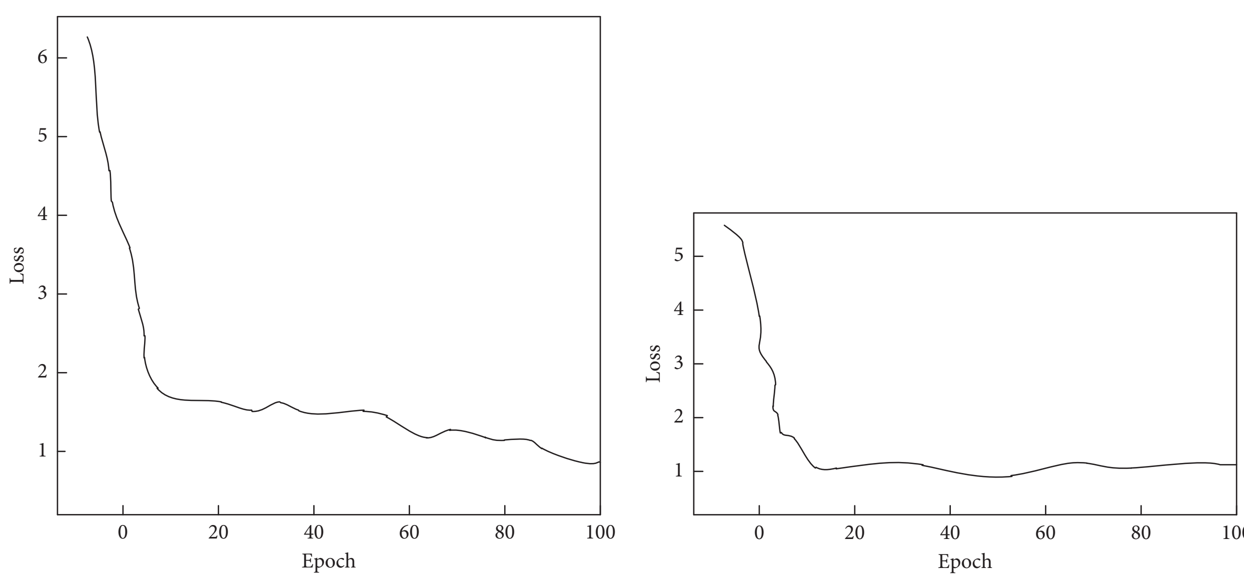


Figure 6: Standard LBP operator.



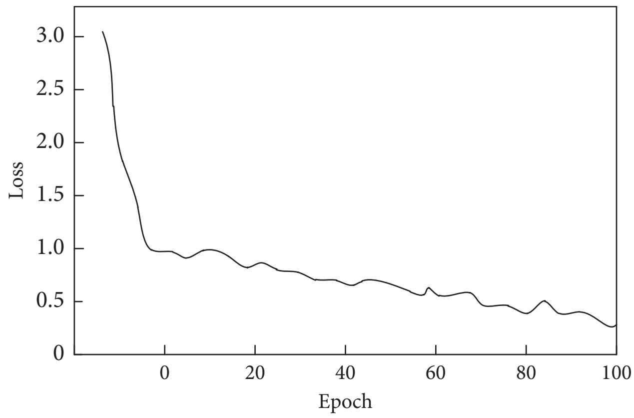
(a) (b) (c)

Figure 7: Diffusion LBP operator. (a) $LBP_{4,1}$, (b) $LBP_{8,1}$, and (c) $LBP_{8,2}$.



(a) (b)

Figure 8: Continued.



(c)

Figure 8: CK + loss function value, period number curve. (a) Reference [5] algorithm, (b) reference [6] algorithm, and (c) proposed algorithm.

Table 1: Comparison of recognition rates of different methods.

Algorithm	Recognition rate (%)
Reference [5] algorithm	91.17
Reference [6] algorithm	89.25
Proposed algorithm	94.12

5. Conclusion

In this paper, the locality preserving projection (LPP) algorithm and sparse representation method are studied, and they are combined to carry out face recognition. By using the locality preserving projection (LPP) algorithm to reduce the dimensionality of the high-dimensional face data, this method can maintain the consistency of the local neighbor relationship between samples before and after dimensionality reduction and effectively ensure the invariance of the relationship between the high-dimensional data in the projection to the low-dimensional space. After dimensionality reduction, the sparse representation method is used to classify and match the feature data to achieve recognition effect. Experimental results show that the proposed method achieves a high recognition rate on CK + expression datasets.

Data Availability

The datasets used and/or analyzed during the current study are available from the author on reasonable request.

Conflicts of Interest

The author declares that he has no conflicts of interest.

Acknowledgments

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Research Article

Application of Improved Boosting Algorithm for Art Image Classification

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In the field of computer science, data mining is a hot topic. It is a mathematical method for identifying patterns in enormous amounts of data. Image mining is an important data mining technique involving a variety of fields. In image mining, art image organization is an interesting research field worthy of attention. The classification of art images into several predetermined sets is referred to as art image categorization. Image preprocessing, feature extraction, object identification, object categorization, object segmentation, object classification, and a variety of other approaches are all part of it. The purpose of this paper is to suggest an improved boosting algorithm that employs a specific method of traditional and simple, yet weak classifiers to create a complex, accurate, and strong classifier image as well as a realistic image. This paper investigated the characteristics of cartoon images, realistic images, painting images, and photo images, created color variance histogram features, and used them for classification. To execute classification experiments, this paper uses an image database of 10471 images, which are randomly distributed into two portions that are used as training data and test data, respectively. The training dataset contains 6971 images, while the test dataset contains 3478 images. The investigational results show that the planned algorithm has a classification accuracy of approximately 97%. The method proposed in this paper can be used as the basis of automatic large-scale image classification and has strong practicability.

1. Introduction

Art image classification is one of the most significant research topics with great significance in which a great deal of information is available to people with the help of advancements in computer technology [1, 2], multimedia technology [3], and network technology [4]. In the United States, it took thirty-eight years for broadcasting users to reach 50 million, thirteen years for TV, and only four years for dial-up Internet to reach 50 million. Major corporations, banks, commercial departments, and scientific research departments have amassed vast amounts of data and information. The traditional statistical analysis makes it difficult to obtain the inherent relationship and implicit information of data attributes because of so much data gathered together. As a result, data mining has emerged as a new technology in the computer field. Data mining is the procedure of determining the relationship between models and data in huge amounts of data using various analysis tools, and these models and relationships can make predictions. Data mining [4] can reveal the connection and potential relationship between them. Image classification is a classic problem of concern in image dispensation via data mining. The purpose of image classification is to use characteristics to determine the categories of source images.

There are several approaches to solving this problem, including the AdaBoost algorithm, K-nearest neighbor (KNN), artificial neural network (NN), and support vector machine (SVM). In 1989, Schapire proposed the boosting algorithm [5]. The name given to this improved boosting algorithm is adaptive boosting (AdaBoost) algorithm, which solved many practical problems in the early boosting algorithm. Boosting algorithms have been used in many fields in recent years, including text mining, multiclass classifications [6], and multilabel situations [7] and natural language understanding. Further, it can be used when combined with other methods such as neural networks [8], decision trees [9], and other algorithms. The boosting algorithm can be used for text classification in text mining [10]. The AdaBoost [11] extended algorithm is used which can handle multiclass [11] and multilabel situations [10]. Furthermore, the boosting algorithm is used in image classification retrieval [12], natural language understanding [13], and speech recognition [14]. The basic idea behind the boosting algorithm is to build a complex and accurate strong classifier using a specific method of some simple, less accurate weak classifiers. The goal of the so-called weak learner is to find a weak classifier for training samples that fit a specific distribution, and its accuracy is only slightly better than random guessing, i.e., greater than 50%. This is always available because the classifier can be reversed if the accuracy falls below 50%. Through repeated iterations, the boosting algorithm generates a weak classifier. The main contributions of the proposed study are listed below:

(i) First, the related work is investigated in the domain of image classification and it is found that 92% is the highest accuracy that is achieved during image classification.

(ii) Second, the most efficient classification algorithm is selected, i.e., SVM, and combined with boosting algorithm.

(iii) Third, from the combination of SVM and boosting algorithm, an improved AdaBoost algorithm is designed.

(iv) Fourth, the algorithm is improved to classify art images and real images.

(v) Finally, from the experimental work, accuracy of above 97% is achieved, which is much better than other researchers' works.

The rest of the paper is organized as follows. Section 2 represents related research work. Section 3 depicts the improved boosting algorithm in art image classification. Section 4 gives simulation results and experimental analysis. Section 5 concludes the paper.

2. Related Work

Image classification is a well-known concern in image handling. The aim of image classification is to use the features of the input image to predict the categories. For this, the authors in [15] focused on remote sensing picture categorization using the expectation-maximization algorithm. Their proposed method is primarily intended to increase the organization accuracy of the EM technique, which currently has 83.8% accuracy in remotely detected image organization. Furthermore, the authors of [13] focused on terrestrial cover image organization by the C4.5 method. The primary goal of this effort is to improve the performance of image organization of urban terrestrial cover maps. The C4.5 technique operates in the following way. Every node corresponds to a value range of the characteristic. Each node ties a range of values of the characteristic. Each node's root defines the approximate attribute value. More information is required to describe the data. Through the pruning process, the C4.5 technique automatically removes preventable nodes. In image classification, this technique achieves an accuracy of 84%. Comparably, in [16], the authors debated on an introduction to classification and regression tree (CART). They explained how to improve the organization correctness of AVIRIS and Landsat digital pictures. The decision tree organization is a nonparametric shape recognition technique. Their proposed CART comprises the identification and building design of a decision tree that is based on training model data for accurate classification. This consists of a root node that can exist in the organization and regression tree. The root node is further subdivided into two subnodes. A subnode may have a grand subnode. This procedure was terminated when no additional splits were likely due to absence of data. In a remote sensed digital image, this method has a classification accuracy of 92.9%.

The authors of [17] defined feature selection using a genetic algorithm and other organization algorithms such as KNN, NN, and MLPNN to categorize the lung picture dataset. This system was tested with lung images and produced acceptable results in the image classification of lung diseases. The genetic algorithm uses the population search method to move from one set of points to another in a single iteration. The GA method consists of three steps: crossover, mutation, and selection. In lung image datasets, this method has a classification accuracy of 90%. In addition, the authors of [18] concentrated on improving classification performance in color retinal images by employing the K-means technique. The K-means classification algorithm is the best example of a general hard organization algorithm. This method is being tested on hundred pictures received from different clusters' centers. All of the pictures are detectable on the optic disk. This study displays that using a color retinal image improves classification accuracy, whereas the authors of [19] suggested a technique called chaos genetic algorithm to improve the accuracy of remote sensing pictures. The CGA technique was used in the optimization process for remote sensing image organization. The GA approach uses a chaos genetic algorithm to optimize problems. In the early stages of the method, this system estimates the optimal population. Image classification accuracy can be improved with remote sensing technology. In image organization, this technique can be distributed into supervised approaches and unsupervised approaches.

The researchers of [20] conducted an analytical technique for image junk organization using an artificial neural network in their work. It is a useful technique in image organization for locating and resolving feature extraction issues. Backpropagation neural network (BPNN) is used in this activity. The artificial neural network can be distributed into 3 layers: input layer, hidden layer, and output layer. The neurons are linked together to form these layers. During the training phase, each neuron automatically adjusts the weights. The classification success is affected by comparing the actual results to the goal value. By using spam images, this technique achieves 93% accuracy in image organization. The authors of [21] discovered a decent organization technique that could attain high classification accuracy when dealing with remote sensing picture classification. ELM is a feed-forward neural network technique. In remote sensing image classification, it is possible to elucidate the training set problem. The extreme learning machine is made up of 3 layers: an input layer, a hidden layer, and an output layer. Using remote sensing image organization, this planned technique achieves roughly 90% accuracy in image classification.

In this regard, the authors of [22] proposed a method for classifying hyperspectral images using the random forest (RF) algorithm. The classification job is completed using both unlabeled and labeled data. Recently, the RF classifier technique for image classification was suggested. This method is an ensemble classification technique that employs a group of classifiers. For classification, this classifier employs a large number of separate decision trees. In image classification, the decision tree technique achieved an overall accuracy of 73.58%, while the semisupervised random forest method accomplished an accuracy of 82.63%. The authors in [23] described data clustering algorithm for image organization in Landsat pictures. Artificial neural network and fuzzy intervention are used in the data clustering method. It completes the training data in a short period. This method is used to determine the image classification accuracy in Landsat images. In image organization, this technique has an accuracy of 88.64%. Eventually, the authors of [24] focused on improving the accuracy of pecan defect organization by employing the AdaBoost algorithm. The AdaBoost method outperforms other methods in terms of classification accuracy. This research suggests that the AdaBoost classifier is appropriate for real-time applications. This technique can also be used for fresh agriculture classification jobs. The AdaBoost classifier method works well in poor marking and accurately in pecan defect organization. In the classification of pecan defect images, their method achieved 92.2% accuracy.

Inspired from the work of above scholars, this research work focuses on the improved boosting algorithm in art image classification by adapting the AdaBoost technique to improve the accuracy of image classification. The experimental results show that the proposed algorithm significantly improves conventional traditional image classification accuracy while also reducing testing computational time. This method has image classification accuracy above 97%.

3. Improved Boosting Algorithm in Art Image Classification

The traditional decision tree algorithm is replaced in this article by AdaBoost as the main framework and the linear SVM as the meta-classifier. Based on the similarity of different matrices, the HOG feature extraction can obtain the image's pixel matrix dispersal and determine whether the goal belongs to the same category. Given the possibility of overfitting due to the lack of data, a stochastic gradient descent (SGD) algorithm is used to enhance the objective purpose while avoiding local optimization [25]. The classifier model used in this paper is depicted in Figure 1, which shows how an SVM classifier has been used to assign test images

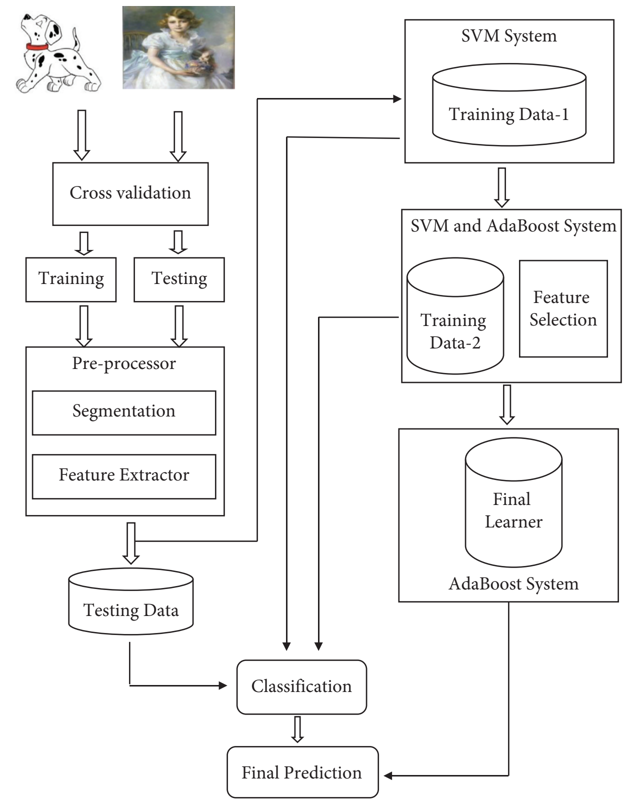


Figure 1: Flowchart of improved boosting algorithm.

regarding the distribution of the original training data (called training data-1). The AdaBoost and SVM system concentrates on selecting the features of AdaBoost. AdaBoost derives a fresh training set, training data-2, from the original training set by reducing noise and uncertainty. The SVM classifier is then used to classify the test images after it has been trained on training data-2. Following AdaBoost implementation, the AdaBoost system alone employs the final learner model. The last learner model is a new classifier that can directly predict the final test images.

3.1. Classification Target. Image classification can be done in a variety of ways [4]. The majority of classifiers, such as maximum likelihood, minimum distance, neural network, decision tree, and support vector machine, make a final decision about land cover class and require a trained model. Clustering-based algorithms, such as K-mean, KNN, or ISODATA, on the other hand, are unsupervised classifiers, whereas fuzzy-set classifiers are soft classifications that provide more information and possibly a more effective solution. Furthermore, knowledge-based classification, which employs expert knowledge and rules or generates rules from observed data, is gaining popularity. Currently, there has been a lot of attention in combining multiple classifiers. For classification tasks, some researchers combined the NN classifier [11], the SVM classifier [6], or the AdaBoost classifier. The goal of this research work is to combine the AdaBoost algorithm and the support vector machine (SVM) for image classification.

The amount of image data available on the Internet is enormous [9]. When using image search engines to retrieve images, the photos "captured" from the Internet are automatically classified to filter out irrelevant images, improving retrieval efficiency. Many researchers have studied the classification of indoor and outdoor images, urban landscapes, and other landscape pictures. The classification of web images is a multiclassification problem. Usually, the best way to solve a multiclassification problem is to divide it into several two-classification problems. Therefore, the research steps of this paper are to first classify the images found in the WEB image database as cartoons and real images and then classify them as painter's pictures and digital images.

3.2. Feature Extraction. Image feature extraction is a significant step in image classification [11]. Because the image lacks obvious features, the image's features must first be obtained before continuing to content-based image classification. Color and shape features, statistical feature of pixels, and transform coefficient features are some of the features used for image classification [6–8]. Furthermore, some researchers have used algebraic features for image recognition and classification. The result of image feature extraction is frequently a vector or a set of vectors. In this study, k feature vectors are used as image extraction tools. In this step, low-level image color features, edge direction, and so on are extracted. To reflect the spatial characteristics of the object, it is divided into $\mathrm{N}\times\mathrm{N}$ blocks, the color, edge, and other image characteristics are extracted from each subblock, and the characteristics of each subblock are strung to form the overall image characteristics. Here, $N=5$, resulting in a total of $5\times 5=25$ subblocks as shown in Figure 2.

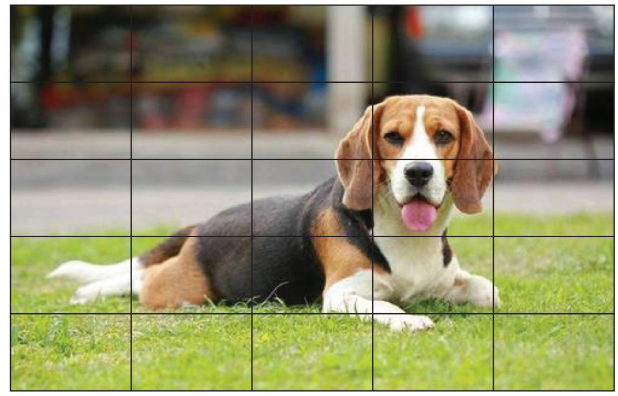


Figure 2: Feature extraction.

3.3. SVM for Classification. To account for the ultimate nonlinearity of the problem, the support vector machine (SVM) approach depends on a linear separation in a high-dimensional feature space where the data have been previously mapped [20]. Assume that the training set is represented in the following equation:

$$X = (x_i)_{t=lR^R}^{l}, \tag{1}$$

where l is the number of training vectors, the base R stands for the real line and the power R is the number of modalities and is labeled with 2 class targets:

$$Y = (y_i)_{t=l}^{l}, \tag{2}$$

where

$$y_i \in \{-1,+1\}\Phi\colon R^R \longrightarrow F. \tag{3}$$

This converts the data into a feature space F, and Vapnik showed that maximizing the smallest distance in F between *(X)* and the separating hyperplane H *(w, b)* reduces the probability of generalization, as shown by

$$H(w,b) = \{f \in F|\langle w, f\rangle_F + b = 0\}. \tag{4}$$

The other kernel in the Gaussian kernel is defined as

$$K(x,y) = \exp\left(\frac{-|x-y|^2}{2\sigma^2}\right), \tag{5}$$

where x and y are feature vectors in the input space and are scale parameters. The Gaussian kernel has two hyperparameters that control its performance: C and the scale parameter.

3.4. Boosting Algorithm. Boosting is based on a machine learning structure. Kearns and Valiant are the first to transform the PAC module's weak learning algorithm, which is only somewhat improved than random guessing, into a strong and accurate learning algorithm, but these algorithms have practical difficulties [23]. Freund and Schapire suggested the AdaBoost algorithm in 1995 to address the practical shortcomings of many early boosting algorithms [16]. The AdaBoost algorithm is a member of the boosting family of algorithms. In this paper, a technique based on dividing the overall classification error into several parts is suggested, inspired by the improved efficiency of the AdaBoost algorithm. The AdaBoost algorithm is used to improve accuracy over the minority class while sacrificing accuracy over the majority class. Algorithm 1 depicts the steps of the proposed AdaBoost algorithm.

The proposed AdaBoost algorithm takes as input the training sample *a*, and *x_i* belongs to the sample space *X*, while *y_i* belongs to the label space *Y*. For two-classification problems, $Y=\{-1, +1\}$. In a series of iterations, i.e., $t=(1,\ldots,\mathrm{T})$, the AdaBoost algorithm repeatedly calls the weak classifier learning algorithm for training. During multiple iterative training, a weak classifier is obtained each time the algorithm runs, as well as the weight of the corresponding weak classifier, and the distribution weight of the sample is also updated accordingly. When the algorithm is initialized, all sample weights can be set to the same value. After each cycle, calculate the classification error and then calculate the new weight of the sample. The error calculation can be seen in the following equation:

(1) Given: (x1, y1),. . ., (xm, ym)
(2) Xi ε X, yi ε $Y = \{-1, +1\}$
(3) Initial samples: D1 (i) = 1/m
(4) Iteration T times, $t = 1, \ldots, T$
(5) Weak classifier learning according to Di
(6) Find the best weak classifier in a weak classifier
(7) H_t: X $\longrightarrow \{-1, +1\}$
(8) Eliminate classification errors and update sample distribution
(9) $D_{t+l}(i) = (D_t(i)\exp(-a_t y_t h(x_i))/Z_t)$
(10) Strongest output classifier:
(11) $H_x = \mathrm{sign}(\sum_{t+1}^{T} \alpha_t h(x_i))$

Algorithm 1: Improved AdaBoost algorithm.

$$\begin{aligned}\varepsilon_t &= Pr_{i-Di}[h(x_i) \neq y_i]\\ &= \sum_{h(x_i)\neq y_i} D_t(i).\end{aligned} \tag{6}$$

When the weak classifier h is obtained, AdaBoost selects the parameter a to represent the weight of h. For h of binary classification, α_t is generally set as

$$\alpha_t = \frac{1}{2}\ln\left(\frac{1-\varepsilon_t}{\varepsilon_t}\right). \tag{7}$$

When t is obtained, use the formula in Figure 2 to recalculate D_t to obtain the updated sample weight. In the t^{th} iteration, the weight of the training sample x_i is marked as $D_t(i)$. In each iteration, the weight of the incorrectly classified sample increases, and the weight of the correctly classified sample decreases. In this way, the weak learner can focus on training the samples that are difficult to classify. Each iteration of the algorithm obtains a binary weak classifier as follows:

$$h_t\colon X \longrightarrow \{-1, +1\}, \tag{8}$$

and the last strong classifier H is a weighted linear mixture of T weak classifiers with the weight α_t as the coefficient.

Boosting algorithm has distinct advantages when compared to other machine learning algorithms [2]. The boosting algorithm works by combining weak classifiers to create a strong classifier. Boosting, as shown in Figure 3, selects the best weak classifier for data classification in turn. It is likely to resolve very complex classification problems by combining simple weak classifiers. If the weak classifier used in the learning process is only based on one dimension in the feature, the boosting training process can also be viewed as a feature selection process.

4. Experimental Results and Discussion

4.1. Experimental Work and Results. This part of the paper describes the experiments that were carried out and the simulation results that were obtained because of those experiments. Several simulation experiments were carried out on art image classification using an improved AdaBoost algorithm. To assess the efficacy and standardization of image classification, in this section, high-quality, standard, open, and universal image datasets are used. These datasets consist of 10471 images to conduct classification experiments, and these images are randomly categorized into 2 parts, which are used as training data and test data, respectively. The training data consist of 6971 images, while the test data consist of 3478 images. Table 1 depicts the image dataset. An art image classification model was developed for using it in the real world. Note that all experiments were carried out on a laptop (Intel Core-i5, 11th generation, having a processor of 2.7 GHz, RAM of 32 GB, and Windows 7 OS).

Figure 4 illustrates the summary of images selected for the experimental work. These images were of two kinds, i.e., cartoons images and photorealistic images. The photorealistic images consisted of painting images and simple photos. To achieve better accuracy, these images were divided into two sets: one is the training set while other is the test set. A total of 4147 cartoon images were taken and divided into training set and test set. The training set consists of 2735 cartoon images while test set consists of 1412 cartoon images. Besides, the painting images of photorealistic images were divided into training and testing sets (i.e., training set = 815 painting images and test set = 408). Similarly, the photo category of photorealistic images is also divided into training and testing sets (i.e., training set = 3321 painting images and test set = 1665).

These images come from several websites. The cartoon images and Chinese traditional paintings were downloaded from http://www.sucaiw.com, and world famous paintings were downloaded from http://www.liuzhong.xm.fj.cn/xkzyk/jxzyk/art. Similarly, the natural images were downloaded from http://wang.ist.psu.edu/image. Cartoon images include cartoon icons, cartoon paintings, etc., as shown in Figure 5; paintings are composed of world famous paintings and Chinese traditional paintings, as shown in Figure 6; photos are composed of natural scenery, world famous paintings, Chinese traditional paintings, characters, and animals, plants, buildings, etc., as shown in Figure 7.

It can be seen from the test results that the first basic combination of image features has the highest test accuracy rate of 91.8%. After adding the color moments of the RGB and HSV color spaces, the composition is the second feature combination. The experimental result is that the highest test

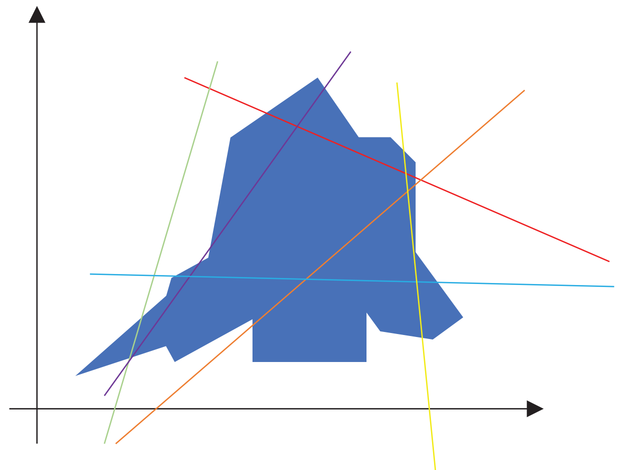


Figure 3: Classification-boosting algorithm.

Table 1: Summary of image data.

Name	Image category	No. of training images	No. of testing images
Cartoons	—	2735	1412
Photorealistic image	Paintings	815	408
	Photos	3321	1665

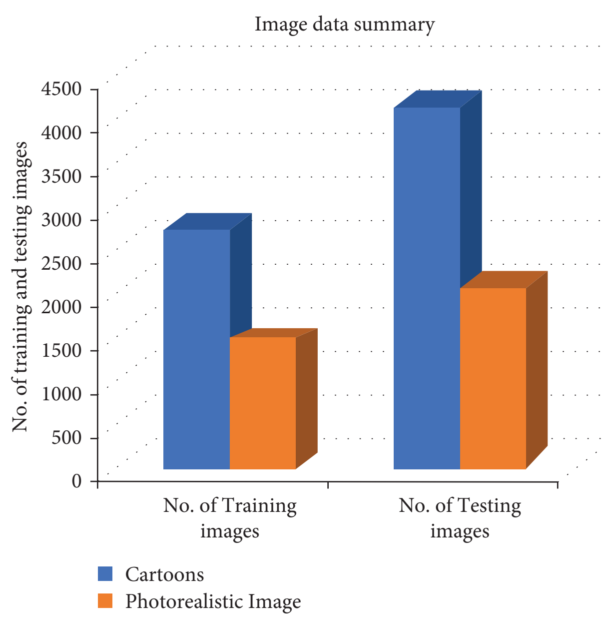


Figure 4: Summary of image data.

accuracy is 94.1%, and the test accuracy is improved by more than 2% compared with the first group of experiments. In paintings and photographs, the feature of color brightness is also very useful for classification. The third feature combination adds a color histogram in the RGB space based on the second feature combination. At the beginning, the accuracy rate has been improved, and the highest accuracy rate is 92.5%, but there is a phenomenon of overfitting. Also, the accuracy rate dropped quickly. The fourth feature combination (6 feature combinations) adds a new feature on the basis of the previous combinations, that is, the color variance histogram in the RGB space. The result is the best, and the highest test accuracy is reached (97.0%), which is 5.2% higher than the first feature combination. Finally, a set of experiments was conducted. Based on the first feature combination, only adding the color variance histogram in the RGB space, the highest test accuracy reached 95.8%, which is higher than the test accuracy of the first feature combination (4%). Table 2 describes the relevant data of the node with the highest test accuracy in the experimental results of cartoon image.

Figure 8 explains the classification prediction of the system based on the obtained confusion matrix:

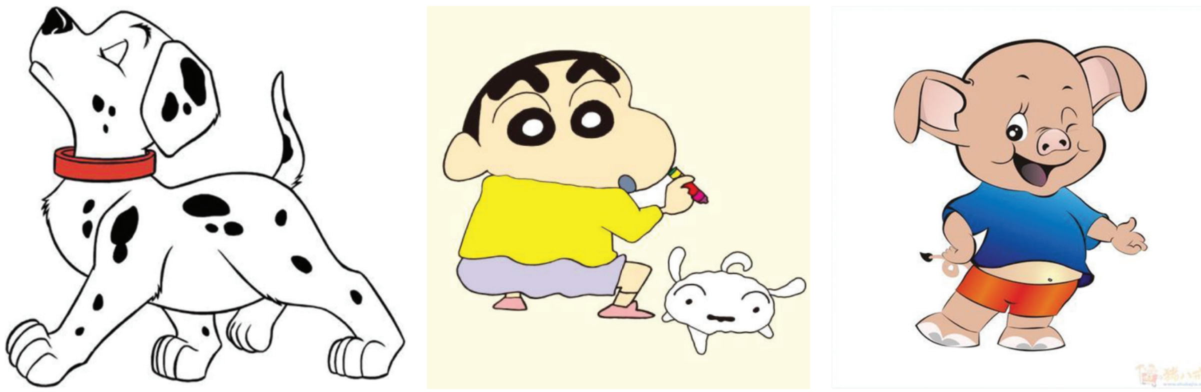


Figure 5: Cartoon image.

Figure 6: Natural scenery in real word.

$$\text{confusion matrix} = \begin{bmatrix} 44.35 & 5.61 \\ 2.29 & 47.75 \end{bmatrix}. \tag{9}$$

The accuracy of the improved AdaBoost algorithm was calculated using this confusion matrix. Accuracy is the percentage of correct predictions based on the test data. It can be calculated by dividing the number of correct predictions by the total number of predictions, as shown in the following equation:

$$\text{accuracy} = \frac{(\mathrm{TP} + \mathrm{TN})}{\mathrm{TP} + \mathrm{FP} + \mathrm{TN} + \mathrm{FN}}. \tag{10}$$

The accuracy obtained is listed in Table 3. The table shows that the lowest accuracy rate of 50 weak classifiers was achieved during feature combination 3, which was 92.5%, but the highest accuracy rate was reached for 300 weak classifiers during feature combination 4, which was 98. So, the proposed algorithm achieved above 97% accuracy by average.

Figure 9 describes the accuracy of the proposed improved AdaBoost algorithm for various values obtained in confusion matrix by performing multiple experiments.

4.2. Discussion. Using the extracted feature and the boosting algorithm, training was conducted on the image training set and then the image test set was tested. According to the above analysis, the following feature combinations were designed to verify the color variance proposed. The histogram and the CM of the HSV color space distinguish the color brightness. The following is the combination of features proposed in this study. Like previous research, the two features of CM LUV and EDH were combined as a reference for experimental data, namely, CM LUV + EDH, with 475 dimensional features. CM of the other two color spaces were added to compare with the first experiment, namely, CM LUV + CM RGB + CM HSV + EDH, with 775 dimensional features. There are five features combined together, namely, three color space CM, one EDH, and one RGB color space histogram, that is, LUV CM + RGB CM + HSVCM + EDH + HSTRGB, with a total of 2375 dimensional features. Put the RGB space color variance histogram to see the impact of this feature on image classification. A total of 6 features have been combined, namely, LUV CM + RGB CM + HSVCM + EDH + HSTRGB + VHSTRGB, with a total of 3975 dimensional features.

Figure 7: Traditional paintings.

Table 2: Picture classification prediction.

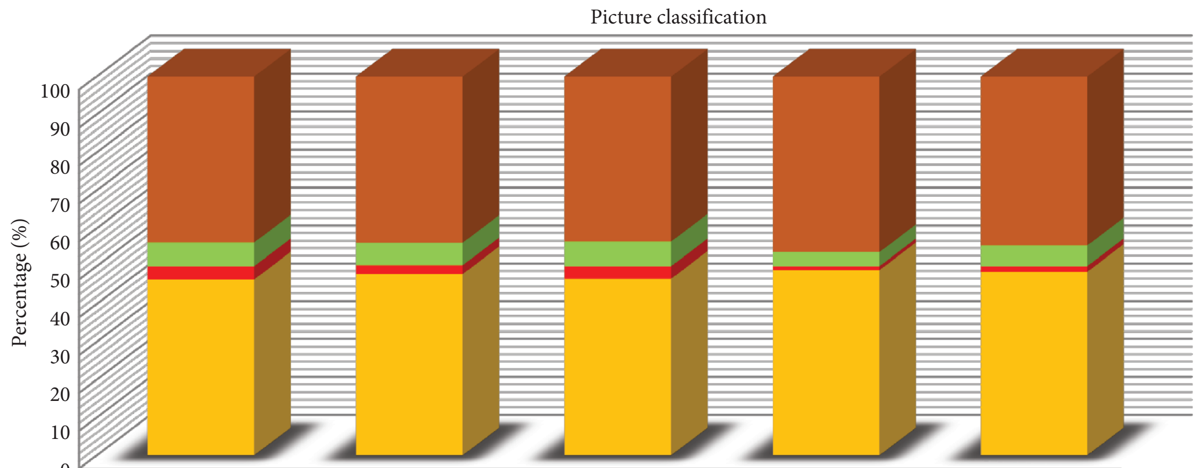
Feature combination	Number of weak classifiers	TP (%)	FN (%)	FP (%)	TN (%)
1	220	93.1	6.9	12.6	87.4
2	340	96.4	4.6	12	88
3	50	93.5	6.5	13.1	86.9
4	300	98	2	7.5	92.5
5	400	97.1	2.9	11	89

Table 3: Picture classification prediction accuracy.

Feature combination	Number of weak classifiers	Accuracy (%)	TP (%)	FN (%)	FP (%)	TN (%)
1	220	92.7	93.1	6.9	12.6	87.4
2	340	95.1	96.4	4.6	12	88
3	50	92.5	93.5	6.5	13.1	86.9
4	300	98	98	2	7.5	92.5
5	400	94.6	97.1	2.9	11	89

Cartoon images and photorealistic images are classified and learned on the training set, and the trained classifier is used to classify the test data. The test data here are all the same. The classification accuracy rate on the test data is shown in Figure 10.

As shown in Figure 10, the vertical axis Y represents the accuracy of test classification (%), from 60% to 100%. The horizontal axis shows that the boosting algorithm was used, and the number of weak classifiers selected ranges from 20 to 400.



	Feature combination 1 for 220 weak classifiers	Feature combination 2 for 340 weak classifiers	Feature combination 3 for 50 weak classifiers	Feature combination 4 for 300 weak classifiers	Feature combination 5 for 400 weak classifiers
TN	87.4	88	86.9	92.5	89
FP	12.6	12	13.1	7.5	11
FN	6.9	4.6	6.5	2	2.9
TP	93.1	96.4	93.5	98	97.1

Figure 8: Picture classification.

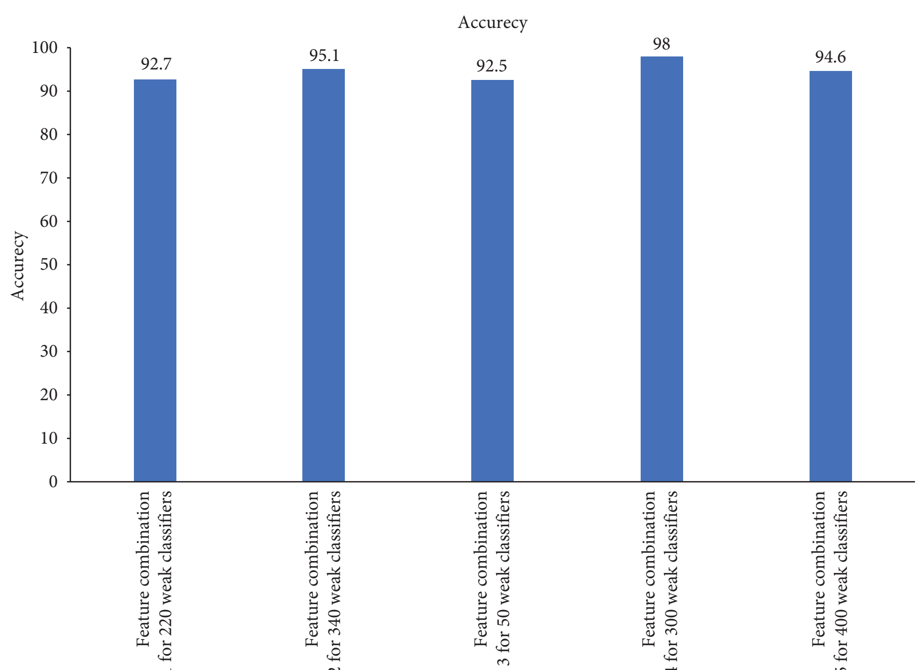


Figure 9: Accuracy of picture classification.

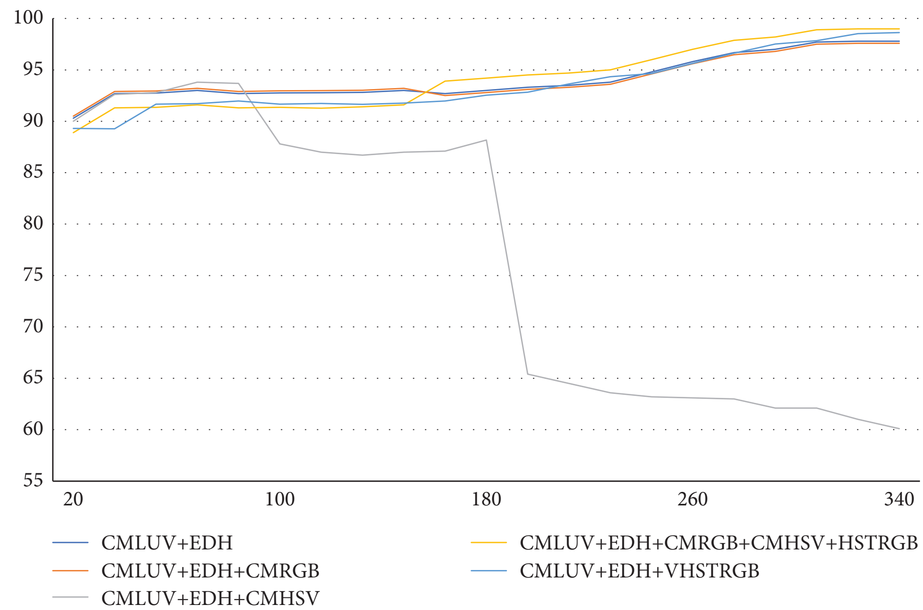


Figure 10: Classification results of cartoons.

5. Conclusion

Through the analysis of various images in the image library, this paper proposes to use the characteristics of the color variance histogram to classify cartoon images/realistic images and to express the variance of the color distribution after quantization in the color space, as a reference feature for classification. Experiments have proved that in image classification, the new feature color space variance histogram proposed in this paper has a good effect on the classification of cartoon images/realistic images and the classification of painting images and photo images, which can improve the classification accuracy. In the process of researching painting images/photographic images, it is found that the brightness of tones is also a very important difference for different types of images. Generally, the paintings are slightly dim. This study uses the color moments of RGB and HSV space to improve the accuracy of image classification. Experiments show that these two features also have an obvious role in distinguishing images.

Data Availability

The datasets used during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Research on Credit Evaluation of Financial Enterprises Based on the Genetic Backpropagation Neural Network

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In this paper, an improved neural network enterprise credit rating model, which is grounded on a genetic algorithm, is suggested. With the characteristics of self-adaptiveness and self-learning, the genetic algorithm is utilized to adjust and enhance the thresholds and weights of the neural network connections. The potential problems of the backpropagation (BP) neural network with slothful speed of convergence and the possibility of falling into the local minimum point are solved to a convinced degree using the genetic algorithm in combination. The hybrid technique of the genetic BP neural network is applied to a credit rating system. Using commercial banks' datasets, our experimental evaluations suggest that, using a combination of the BP neural network and the genetic algorithm, the proposed model has high accuracy in enterprise credit rating and has good application value. Moreover, the proposed model is approximately 15.9% more accurate than the classical BP neural network approach.

1. Introduction

At present, the traditional method of proportional analysis is still mainly used to evaluate the credit of enterprises in the Republic of China. The biggest disadvantage of this method is that the determination of indicators and weights in credit evaluation has great subjectivity, which is bound to increase the credit risks of commercial banks. In this paper, a credit rating model based on the BP neural network, which is further enhanced and optimized, by a genetic algorithm is proposed. The proposed model could significantly reduce the inaccuracy of credit rating caused by human factors to a certain extent. Using genetic algorithm, the initial weight and threshold of the backpropagation (BP) neural network are optimized, and the range of weight is increased to solve the two shortcomings of the BP neural network, which are (i) slow convergence speed and (ii) falling into the local minimum. Through combining the BP neural network with the genetic algorithm, the advantages of both are complementary.

The chief technique for commercial banks to investigate enterprise credit risk is using linear combination methods to complete the credit rating of all enterprises according to certain evaluation indexes. However, subject to the one-sidedness and randomness have always been the fatal drawbacks of these rating methods. Therefore, it is essential to look for alternative methods such as machine learning and artificial intelligence to improve the optimization of current credit rating systems in China. To evaluate the enterprise credit rating widely, competently, quantitatively, precisely, and suitably, this paper uses the classical genetic algorithm, one of the widely used optimization algorithms, to enhance the thresholds and weights of the classical BP neural network (NN) to establish a credit rating model for an enterprise, which is grounded on the new genetic algorithm integrated into the BP neural network. The main characteristics of the proposed model are (i) fast convergence speed, (ii) global optimization, and (iii) accurate evaluation of the credit rating. The credit rating model well adapts dynamically to the work of enterprise credit rating and has certain application value. The following are the main innovation points of this paper:

(1) This paper proposes a credit rating approach grounded on the BP neural network that uses the classical genetic algorithm to increase the model accuracy and generate reasonable rating recommendations

(2) Characteristics such as self-adaptiveness and self-learning of the classical genetic algorithm are utilized to modify, enhance, and improve the thresholds and weights of the neural network connections

(3) Experimental results and our evaluations on real datasets show that the suggested hybrid genetic BP neural network model has higher accuracy as compared to the classical BP neural network

The structure of the remaining part of this paper is as follows. Section 2 describes the details of the background and state-of-the-art-related works. In Section 3, we discuss the methodology used to establish a credit rating system. Section 4 builds a BP neural network model. In Section 5, we integrate the genetic algorithm into the BP neural network and illustrate the experiments and results. Finally, Section 6 concludes this paper along with several key directions for further research and investigation.

2. Related Work

Artificial neural network (ANN) is an intelligent information processing technology that reproduces the information processing procedure of the human brain. It has strong robustness, self-adaptability, and self-organization and and is good at association, synthesis, and promotion [1]. These models illustrate and mimic diverse stages of the biological neural system with respect to various angles. The BP neural network model discussed in this paper is one of them. The idea of the BP neural network algorithm is as follows. First, a small random number is used to represent the connection weight and bias weight of each unit, and then, secondly, a group of training sample data is selected. The calculation process is mainly divided into two processes: (i) the forward process, which transfers the input to each unit and (ii) finally obtains the output at the output node of the network [2]. In the reverse process, the error between the actual output of the network and the expected output of the network is returned to the input layer from the output layer through the middle layer. Note that the offset weight and the connection weight are continuously adjusted in this process. Finally, the error between the actual output and the expected output of the training sample is less than the expected error given in advance [3].

Genetic algorithm is a computational model that illustrates and simulates the natural selection and genetic approach of the biological development and evolution process. Genetic algorithm is an approach for the exploration of the optimum solution through mimicking the process of natural evolution [4]. Moreover, genetic algorithm views the problem space in the way of coding space, with the coding population as the basis of evolution and the fitness function as the basis of evaluation. The individual bit string in the whole population is selected, crossed, and mutated to simulate the biological evolution and complete an iterative process. After multiple iterations, the individual evolution in the population will be completed, and the optimal solution is finally obtained [5, 6].

3. Establishment of the Credit Rating Model

3.1. Index Selection of the Rating Model. At present, the main method for commercial banks to analyze enterprise credit risk is to use linear combination methods to complete the credit rating of all enterprises according to the four key evaluation indexes of enterprise credit [7, 8]. However, subjective one-sidedness and randomness have always been the fatal drawbacks of these rating methods [9]. Therefore, to establish a comprehensive and scientific index evaluation system, it must be based on appropriate financial regulations and must follow the overall requirements of easy access, concise and reasonable, comprehensive, complete, strong operability, and stability. Based on referring to the credit rating system structure of foreign enterprises and combining it with the actual situation of domestic enterprises, according to the basic principle of combining qualitative indexes with quantitative indexes and potential abilities with practical abilities, the following enterprise credit rating index system structure is established. The index system is composed of approximately 26 indexes. Moreover, the network structure of this enterprise credit rating model depends on these 26 indexes. The rating index system is shown in Table 1.

3.2. Index Data Normalization. Among the 26 indicators, as shown in Table 1, eight secondary indicators of external environment enterprise quality are discrete nonnumerical data. Therefore, to speed up the learning speed, we need to scale the discrete nonnumerical data in equal proportion so that the scaled results fall into a certain range. Moreover, to prevent the large numerical information from drowning the small numerical information in the scaling process, we need to use the normalization method to deal with each input item. For the input vector set $X = \{x_1, x_2, \ldots, x_n\}$, the following formula, as illustrated by equation (1), is used to normalize and scale the input data (where x_i' is the result of x_i' normalization processing) [10, 11].

$$x_i' = \frac{x_i - \min(X)}{\max(X) - \min(X)}. \tag{1}$$

Let us assume the operator quality, nonnumerical discrete data, as an example to illustrate the normalization method. For example, if the value of the operator quality attribute is that the enterprise leaders have rich field knowledge and management experience, then the score is defined as 4 [12]. Note that 6 is the maximum value of the attribute score, while 0 is the minimum value. Thus, according to equation (1), the normalized attribute value v is given by

Table 1: Enterprise credit rating index system.

First-level indicators	Secondary indicators	Method
External environment and enterprise quality	Development prospects	Qualitative
	Policy and regulation environment	Qualitative
	Business order and credit environment	Qualitative
	Quality of leaders	Qualitative
	Enterprise performance	Qualitative
	Management decision	Qualitative
	Production layout	Qualitative
	Credit record	Qualitative
Economic strength	Asset ratio	Qualitative
	Return on cash flow of total assets	Qualitative
	Interest cover	Ration
Operating efficiency	Sales profit margin	Ration
	Net interest rate of assets	Ration
Solvency	Asset liability ratio	Ration
	Current ratio	Ration
	Quick ratio	Ration
	Contingent negative ratio	Ration
	Ratio of cash flow to current liabilities	Ration
Operating capacity	Product sales rate	Ration
	Turnover of current assets	Ration
	Turnover of the whole assets	Ration
Profitability	Net profit rate of sales	Ration
	Gross profit margin of sales	Ration
	Profit rate of net assets	Ration
	Return on the whole assets	Ration
	Growth rate of net assets	Ration

$$v = \frac{4-0}{6-0} = 0.67. \quad (2)$$

For qualitative data, with given maximum and minimum values, the above method can also be used for normalization and scaling purposes.

4. Construction of the BP Neural Network Model

4.1. Selection of the Hidden Layer Number. Previous research has shown and proved for a long time that this does not account for in what way how much complex the function of mapping is; indeed, one hidden layer is potentially adequate to encounter the requirements [5, 7, 13]. Therefore, this paper also assumes the previous findings of researchers and scholars and chooses just a solitary hidden layer architecture to shape and design the BP neural network approach for the proposed enterprise credit rating system [14].

4.2. Determination of the Number of Hidden Layer Neurons. The same sample dataset is used to train the network with a different number of hidden layer neurons while waiting for the weight to be altered. Finally, the quantity of hidden layer neurons is estimated using the principle of minimum error. In order to obtain faster error reduction speed, one or two neurons can be added on the premise of solving the problem. Therefore, six is determined as the number of hidden layer neurons.

4.3. Determination of the Transfer Function. Due to the fact that, among the input and the output vector set $X = \{x_1, x_2, \ldots, x_n\}$, there is no linear relationship, therefore, we assume that the neuron transfer function of the classical or optimized BP neural network must be differentiable all over the place. This paper determines the sigmoid function as the transfer function. The sigmoid function is expressed as

$$f(x_i) = \frac{1}{1 + e^{-x_i}}. \quad (3)$$

The function is a nondecreasing continuous function representing the state continuous neuron model in the real number field [0, 1].

4.4. Determination of the Training Times. After a period of the training, the error of the testing model ought to be obtained at this moment in time. It should be noted that the weight value at this time should be kept synchronously updated every time the test error is extracted. If the test error rises, then it means that the network has reached the best training times. Usually, it is well understood that, at the best training time, the weight value of the model currently has the best generalization capability [15].

4.5. Design of the Output Layer. In this paper, to keep everything simple, we assume that the output layer of the proposed credit rating system just wants to imitate the enterprise credit rating; therefore, only and at most only one output layer node is set, which is divided into 10 levels, i.e., scope of the credit rating [16]. The details are shown in Table 2.

4.6. Model Establishment. According to the previous analysis, this paper plans a three-layer, combination of the genetic and BP neural network, model to mimic various credit ratings of the enterprises. The suggested model comprises approximately, or more precisely, exactly twenty-six input layer nodes; that is, the input vector $X = \{x_1, x_2, \ldots, x_n\}$. These input layer nodes correspond to 26 indicators in the enterprise credit rating system. Note that the hidden layer of the proposed model comprises a maximum of six nodes; that is, the hidden layer vector $Y = \{y_1, y_2, \ldots, y_6\}$. There is a node in the output layer, that is, variable O. The value of O represents the actual output credit rating of the enterprise [17].

According to this paper, the output value "O" of the neural network should be in the range of [0, 1]; mathematically, this is illustrated as $O \in \{0, 1\}$. The expected output is the result of transforming the actual output of the training sample into [0, 1], expressed as the vector $D = (d_1)$. Furthermore, the weight values amongst the input and the hidden layers are expressed by the vector $V = \{v_{1,1}, v_{1,2}, \ldots, x_{26,6}\}$, and from the hidden layers to the output layers, they are represented by the vector $W = \{w_{1,1}, w_{2,1}, \ldots, x_{6,1}\}$, respectively. The hidden layer is given by [18]

$$y = f\left(\sum_{i=1}^{26} v_{ij} x_j\right). \tag{4}$$

The output layer is given by

$$O = f\left(\sum_{i=1}^{6} w_{j,1} y_j\right). \tag{5}$$

Note that $f(x)$ is the unipolar sigmoid transfer function selected in this paper, i.e., equation (2). The genetic algorithm-grounded BP neural network architecture of the credit rating model of the enterprise that is established by the above principles is shown in Figure 1.

5. Application Analysis of the BP Neural Network Optimized by the Genetic Algorithm in Enterprise Credit Rating

5.1. BP Neural Network Optimized by the Genetic Algorithm. The calculation of the threshold value and connection weight value of the neurons is the core idea of neural network operation. Genetic algorithm can be utilized to improve and enhance the threshold value and connection weight value between neurons. The global optimization method of the suggested BP neural network using a genetic algorithm is as follows. The genetic algorithm is utilized to improve and enhance the initial threshold value and connection weight value between neurons of the BP neural network. Then, the BP algorithm is applied to modify the threshold value and connection weight value between neurons according to the negative gradient direction, and the network is trained. The major reasons of why this method is utilized to improve and enhance the establishment of the BP neural network include the following: (i) the genetic algorithm can effectively avoid the disadvantage that the search range falls into the local minimum; (ii) it can also reduce the training times of the threshold value and weight value; and (iii) it can advance the speed of convergence of the model. The operation of the BP neural network optimized by the genetic algorithm is described in two steps as follows:

Table 2: Scope of the credit rating.

Output	Credit rating
$0 \geq 0.95$	AAA
$0.95 > 0 \geq 0.85$	AA
$0.85 > 0 \geq 0.74$	A
$0.74 > 0 \geq 0.62$	BBB
$0.62 > 0 \geq 0.48$	BB
$0.48 > 0 \geq 0.36$	B
$0.36 > 0 \geq 0.21$	CCC
$0.21 > 0 \geq 0.12$	CC
$0.12 > 0 \geq 0.09$	C
$0.09 \geq 0$	D

(1) Chromosome coding: because the threshold and weight values of the neural network are continuous parameters and the coding method of the floating-point number is characterized by continuous parameter optimization, therefore, the steps of coding and decoding are omitted. To a certain extent, it can improve the speed of the genetic algorithm operation and the accuracy of the feasible solution. Therefore, this paper chooses the floating-point coding method to encode chromosomes. The threshold and weight values are cascaded according to the input layer node to the hidden layer node and, subsequently, from the hidden layer node to the output layer node. It should be noted that a chromosome in the population is a cascaded output array.

(2) Fitness function: the fitness function value determines the evaluation result of the genetic algorithm for the viability of chromosomes. The larger the fitness function value of the chromosomes is, the easier it is to be selected for genetic operation and, furthermore, the smaller the square sum of the error between the actual output value and the expected output value of the output layer neurons. This shows that the accuracy of the BP neural network is higher. In this paper, the mean square error function of the BP algorithm is selected as the fitness evaluation function. The optimization algorithm of the BP neural network, in terms of the flowchart, is shown in Figure 2.

5.2. Application Analysis of the BP Neural Network in Enterprise Credit Rating. According to the previous analysis, the input layer of the enterprise credit rating model established in this paper has approximately 26 nodes. There

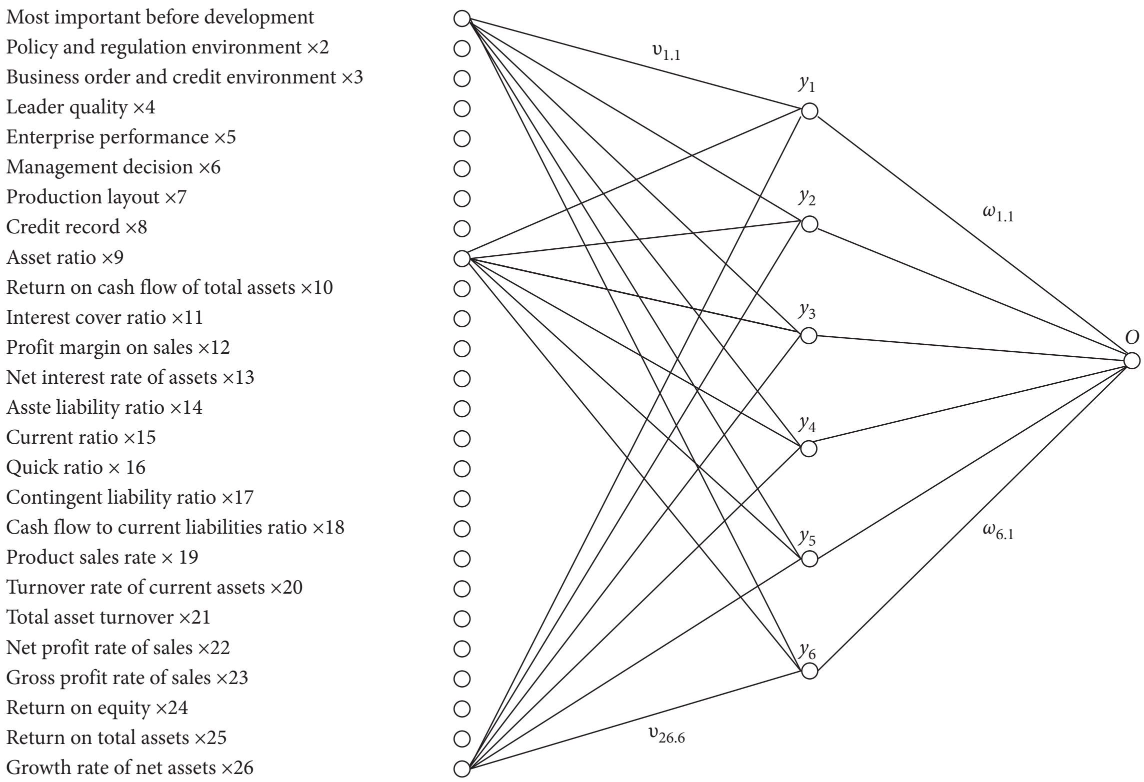

Figure 1: The credit rating model.

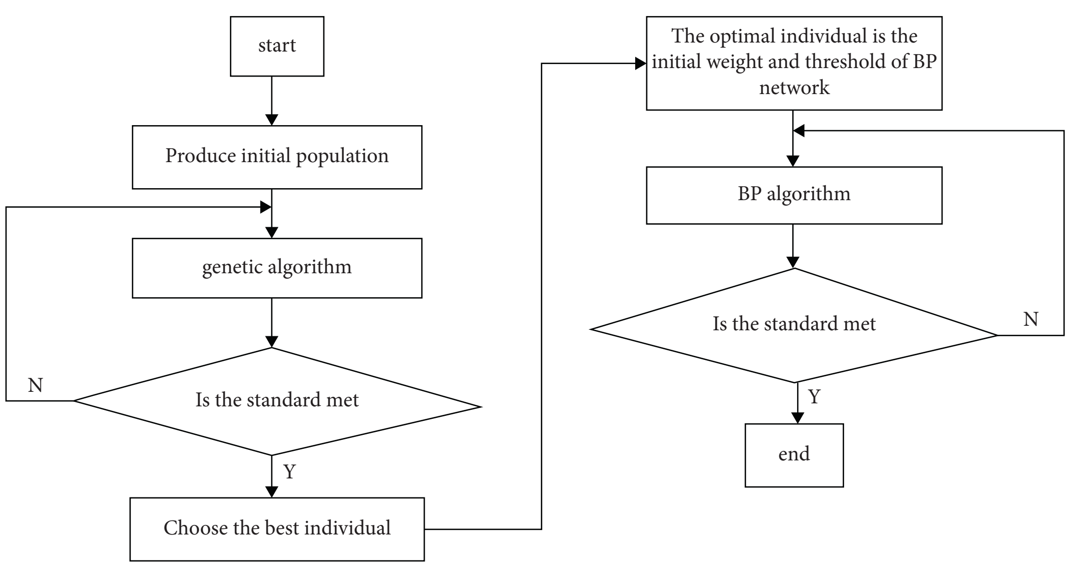

Figure 2: Flowchart of the genetic BP neural network optimization algorithm.

are six nodes in the hidden layer and one node in the output layer. The rating model is nonlinear, and the question whether the model can converge and reach the local minimum or not essentially depends on the initial weights to a large extent. Therefore, this is very important to make the state value of each neuron close to zero when the initial weights are added. At the same time, the experimental results of Stornetta and Huberman show that when the weights are adjusted in the range of [−0.5, 0.5], the state value of each neuron is close to zero. As a result, the convergence time will be shortened by approximately 30% to 50% [19].

The test parameters are as follows: the expected error is 0.005, the unipolar sigmoid function is the transfer function, the initialization of network weights is limited in the [−0.5, 0.5] interval, the selection probability is 0.05, the crossover rate is 0.1, the variation rate is 0.05, and the population size is 300. Moreover, the maximum evolutionary algebra is 1500. The sample learning data used in this paper come from

Table 3: Connection weights of the input layer and hidden layer after training.

Input layer	Hidden layer 1	2	3	4	5	6
1	−0.5349	0.6554	0.3255	0.091	−1.0189	1.1820
2	0.8526	−0.4313	1.2015	−1.0425	0.4017	−0.1709
3	1.1856	1.1660	0.2807	−0.4031	−02354	1.126
4	1.1660	0.2807	−0.3892	0.556	−1.0425	0.8050
5	−0.1402	−0.3642	0.9511	1.2881	0.0406	−0.3059
6	0.1369	0.8786	−1.171	−0.30559	0.2082	0.8186
7	0.5556	0.9290	1.0406	0.1569	1.1369	−0.8414
8	−0.5714	1.2881	0.7082	−0.3678	−0.9727	−0.8135
9	−0.4274	0.4695	0.5004	0.7118	0.9667	1.2990
10	−0.9711	0.1421	1.3295	−0.2142	0.0731	1.0525
11	1.2646	−0.7481	0.774	−0.3154	−0.0107	−0.8469
12	1.0484	−0.9704	1.668	−0.5349	1.2822	−0.4742
13	1.1615	−0.8296	−0.5125	−1.0189	1.4454	0.0091
14	0.6554	0.3255	−0.4586	0.6942	0.8477	−0.4313
15	−0.1584	−0.8720	1.820	0.6670	0.8526	0.8651
16	−0.6971	0.2784	0.5465	−0.6697	0.4232	0.5555
17	0.0552	1.3068	−0.3870	0.3055	−0.6873	0.8310
18	0.4686	0.7038	−0.6208	−0.5677	0.4911	−0.2349

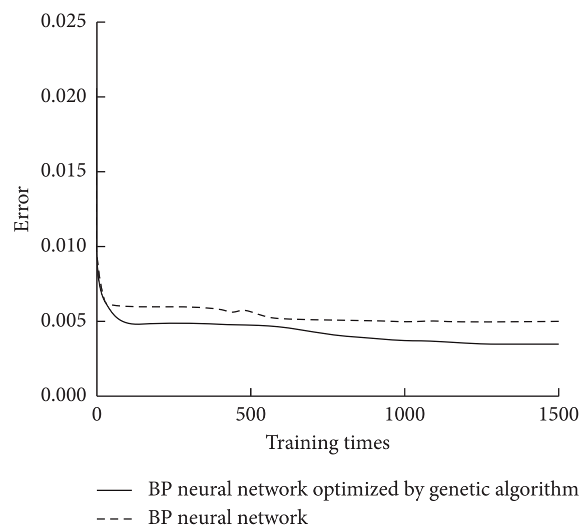

Figure 3: Training results of two kinds of neural networks (genetic algorithm-integrated BP neural network for the credit rating system).

approximately 189 enterprise credit evaluation data samples provided by a bank. When all the training data are input into the network, the input order of each training sample is randomly sorted first and then fed as the input into the model for training. The connection weights of the input layer and hidden layer after the training are shown in Table 3. Our evaluation with these assumptions shows that the BP neural network enhanced through integrating the genetic algorithm can meet the requirements of the training, and the speed of the error is higher than that of the general BP neural network, as shown in Figure 3.

5.3. Model Testing. After completing the training, 78 groups of the enterprise data of a commercial bank are selected and input into (i) the BP neural network and (ii) the BP neural network model optimized by the genetic algorithm for testing, respectively. Simultaneously, the results of the suggested network outcomes are compared with the actual credit rating outcomes. The outcomes of the proposed model testing are illustrated in Table 4.

The prediction accurateness of the credit rating assessment model is measured by the proportion of two kinds of errors: (i) the first kind is that the company's credit rating is wrongly estimated high (for example, the company's actual credit rating is B, and the model misjudged BB) and (ii) the second type of error is that the company's credit rating is underestimated (for example, the company's actual credit rating is A, and the model's misjudgment is BBB). The misjudgment rates of the traditional BP neural network (NN) model and the suggested BP neural network (NN) model optimized and enhanced by the genetic algorithm for the test samples are shown in Table 5. It can be observed from outcomes shown in Table 5 that the proposed BP

Table 4: Model testing results.

Serial number	Expert rating results	BP neural network	Optimization of the BP neural network model by genetic algorithm
1	BB	A	BB
2	A	BBB	A
3	BBB	AAA	BBB
4	AA	A	AA
5	A	B	A
6	BB	BB	B
7	B	BBB	B
8	BBB	BB	BBB
9	BB	A	BB
10	A	A	A

Table 5: Misclassification rate of two models for test samples.

Model	Type 1 error	Type 2 error	Total miscarriage of justice
BP neural network	3 (3.85)	3 (3.85)	6 (7.70)
BP neural network optimized by genetic algorithm	0 (0)	2 (2.56)	2 (2.56)

The rate of misjudgment is in brackets, and the unit is %; the number of misjudgments is outside the brackets.

neural network improved by integrating the genetic algorithm can obtain a high accuracy rate in the enterprise's credit rating [20, 21].

6. Conclusions and Future Work

To evaluate the enterprise credit rating comprehensively, efficiently, objectively, accurately, and conveniently, this paper practices the integration of a genetic algorithm to improve and enhance the thresholds and weights of the BP neural network model. Furthermore, the proposed work finds a credit rating model for the enterprise that is grounded on the classical genetic algorithm. The main characteristics of the proposed model are fast convergence, global optimization, and accurate evaluation of credit rating systems. Our evaluation over certain plausible assumptions demonstrates that the credit rating model can well adapt to the work of enterprise credit rating and has certain application value. The proposed model is approximately 15.9% more accurate than the classical BP neural network approach.

Compared with the classical genetic algorithm, the BP neural network algorithm has significantly enhanced the diversity of new generations, and the performance of the optimized genetic BP neural network has been improved. The enhancement of the mutation possibility boosts the aptitude and speediness of the genetic algorithm for the exploration of the global optimal solution, and the credit rating model has effectual convergence proficiency and accurate prediction accuracy. In the future, we will consider swarm evolutionary algorithms such as PSO and its various variants for integrating into the BP neural network for more robust enterprise credit rating systems [22, 23]. Furthermore, large datasets should be considered to evaluate and generalize the findings of our proposed research and investigation. Other aspects such as security, supply chain, and accurateness of the credit rating system are also of utmost importance to ensure correct and appropriate rating for various enterprises. Researchers at academia and industries are developing blockchain, supply chain management-based approaches to secure and make such systems more robust, accurate, precise, and secure [24, 25].

Data Availability

The data used to support the findings of this study are available upon request to the author.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Key Frame Extraction for Sports Training Based on Improved Deep Learning

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With the rapid technological advances in sports, the number of athletics increases gradually. For sports professionals, it is obligatory to oversee and explore the athletics pose in athletes' training. Key frame extraction of training videos plays a significant role to ease the analysis of sport training videos. This paper develops a sports actions' classification system for accurately classifying athlete's actions. The key video frames are extracted from the sports training video to highlight the distinct actions in sports training. Subsequently, a fully convolutional network (FCN) is used to extract the region of interest (ROI) pose detection of frames followed by the application of a convolution neural network (CNN) to estimate the pose probability of each frame. Moreover, a distinct key frame extraction approach is established to extract the key frames considering neighboring frames' probability differences. The experimental results determine that the proposed method showed better performance and can recognize the athlete's posture with an average classification rate of 98%. The experimental results and analysis validate that the proposed key frame extraction method outperforms its counterparts in key pose probability estimation and key pose extraction.

1. Introduction

With the advent of artificial intelligence, performance analysis in sport has undergone significant changes in recent years. In general, manual analysis performed by trained sports analysts has some drawbacks such as being time-consuming, subjective in nature, and prone to human errors. Objective measurement and assessment for sports actions are indispensable to understand the physical and technical demands related to sports performance [1]. Intelligent sports action recognition methods are developed to provide objective analysis and evaluation in sport and improve the accuracy of sports performance analysis and validate the efficiency of training programs. Common sports action recognition systems can be developed using advanced machine learning methods to process the data collected via computer vision systems and wearable sensors [2]. Sports activities recorded through a computer vision system can be used for athlete action detection, movement analysis, and pose estimation [3]. The vision-based sports action recognition can provide real-time feedback for athletes and coaches. However, the player's actions in sports videos are more complex and skillful. Compared with daily activities, the analysis of sports videos is more challenging. This is because, the players while playing perform rapid and consistent actions within the camera view, thus degrading the action recognition performance [4].

In sports video analysis and processing for action recognition, pertinent and basic information extraction is a mandatory task. If the video is large, then it is hard to process the whole video in a short time while preserving its semantics [5]. The extraction of the key frame is a prime step of video analysis. The key frame provides eloquent information and is a summary of the entire video sequence [6]. A video is normally recorded 30 frames per second and contains additional information for the recognition of a particular computer vision task. Key frame detection is mainly applied in video summarization and visual localization in videos. To use all the frames of a video, more computational resources and memory are required. In many computer vision applications, one or few key frames may be enough to accomplish the desired recognition results [3].

The key frames are applied in many applications such as searching, information retrieval, and scene analysis in videos [7]. The video represents a composite structure and is made of several scenes, shots, and several frames. Figure 1 shows the division of video into shots and frames. In many video and image processing tasks, such as scene analysis and sequence summarization, it is essential to perform an analysis of the complete video. During the analysis of videos, the major steps are scene segmentation, detection of shot margin, and key frame extraction [8, 9]. The shot is a contiguous, adjacent combination of frames recorded by a camera. The key objective of extracting key frames is to extract unique frames in a video and prepare the video sequences for quick processing [10]. In this paper, we propose an effective method for the extraction of a key frame from athlete sports video, which is accurate, fast, and efficient. The proposed key frame extraction model uses a long sports action video as input and extracts the key frames, which can better represent the sports action for recognition. We introduced an improved convolution neural network method to detect key frames in athletes' videos. We performed experiments on athletes' training video dataset to show the triumph of our method for key frames' detection.

We structured the rest of the paper as follows. In Section 2, related work is presented. Section 3 provides the detail of the proposed method. Sections 4 and 5 are about the experimental results and conclusion, respectively.

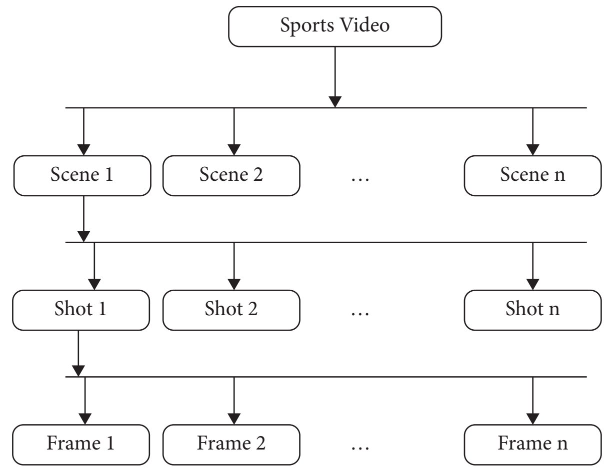


Figure 1: Structure of sport video.

2. Related Work

With the advancement of sports, competition in sports is becoming a base to develop people's social life and emotions. In order to enhance the competitive skills of athletes, active investigation of sports training is one of the central issues. Many previous analysis methods in this field depend on using a segmentation-based approach [11]. These methods usually extract visual features from videos. One of the first attempts discovered local minimum changes within videos concerning similarity between the consecutive frames. Later on, other works augmented this approach by using the key points' detection method for local feature extraction and combining the key points to find the key frames [12]. All of these methods have a common shortcoming of extracting redundant frames rather than fully covering the video contents.

Another group of traditional methods is based on feature clusters and detects the key video frames with prediction of a prominent frame in individual clusters. Zhuang et al. [13] employed the joint entropy (JE) and mutual information (MI) between successive video frames and detected key frames. Tang et al. [14] developed a clustering method for recognizing the key frame using visual content and motion analysis. A frame extraction method for hand gesture images' recognition using image entropy and density clustering was presented in [15]. Cun et al. [16] developed a method for the extraction of key frames using spectral clustering. The feature locality in the video sequence was extracted using a graph as an alternative to relying on a similarity measure shared between two images.

To overcome the shortcomings of traditional frame detection methods, recent works focused on deep learning to perform key frame recognition in videos [17]. Deep learning has made a great breakthrough in the application of speech recognition, vision-based systems, human activity recognition, and image classification [18]. The deep learning models simulate human neurons and form the combination of low- and high-level features, to describe and understand objects [19]. Deep learning is relative to "shallow learning." The major difference between deep learning and "shallow learning" is that the deep model contains several nonlinear operations and more layers of a neural network [20]. "Shallow learning" relies on manual feature extraction and ultimately obtains single-layer features. Deep learning extracts different levels of features from the original signal from shallow to deep. In addition, deep learning can describe learning deeper and more complex features, to better express the image, which is conducive to classification and other tasks. The structure of deep learning is comprised of a large number of neurons, each of which is connected with other neurons. The process of deep learning is to update the weights through continuous iteration. Deep neural networks (DNN) are a deep network structure. The network structure of a deep neural network includes multiple single-layer nonlinear networks. At present, the more common networks can be categorized into feedback deep networks (FBDN), bidirectional deep networks (BDDN) [21], and feedforward deep networks (FFDN).

Different supervised and unsupervised deep learning methods have been suggested for key frame detection in sports videos which considerably enhance the performance of action recognition systems. Yang et al. [22] employed the method of generative adversarial networks for the detection of key frames in videos. For key features' extraction, CNNs were employed to extract the discriminant features which were encoded using long short-term memory (LSTM) networks. Another approach using bidirectional long short-term memory (Bi-LSTM) was introduced in [23]. The method was effective for extracting the highlighting the key video's frames automatically. Huang and Wang [24] proposed a two-stream CNNs' approach to detect the key frames for action recognition. Likewise, Jian et al. [25] devised a unique key frame and shot selection model for summarization of video. Wen et al. [26] employed a frame extraction system through estimation of the pose probability of each neighboring frame in a sports video. Moreover, Wu et al. [27] presented a video generation approach based on key frames. In this study, we propose an improved key frame extraction technique for sports action recognition using a convolutional neural network. FCN is applied to get the ROI for a more accurate pose detection of frames followed by the application of a CNN to estimate the pose probability of individual frames.

3. Methods

3.1. Overview of CNN. CNN is an artificial neural network that mimics the human brain and can grip the training and learning of layered network structures. CNN uses the local receptive field to acquire autonomous learning capability and handle huge data images for processing. CNN is a specific type of FFDN. It is extensively used for recognition of images. CNN represents image data in the form of multidimensional arrays or matrices. CNN extracts each slice of an input image and assigns weights to each neuron based on the important role of the receptive field. Simultaneous interpretation of weight points and pooling functions reduces the dimension of image features, reduces the complexity of parameter adjustment, and improves the stability of network structure. Lastly, prominent features are generated for classification, so they are broadly used for object detection and classification of images.

CNN is primarily comprised of the input layer, convolution layer, pooling layer, full connection layer, and output layer. The input image is given to the input layer for processing. The convolution layer performs convolution operation over the input matrix between the input layer and convolution layer, and the input image is processed for feature extraction. The function of the pooling layer is to take the maximum value of the pixels in the target area of the input image, to condense the resolution of the feature image and avoid overfitting. The full connection layer is composed of zero or more neurons. Each neuron is linked with all the neurons in the preceding layer. The obtained feature vector is mapped to the output layer to facilitate classification. The function of the output layer is to classify feature vectors mapped from the full connection layer and create a one-dimensional output vector, with dimensions equal to the number of classes.

3.2. Deep Key Frame Extraction

3.2.1. Proposed Algorithm. In this section, we provide the details of the proposed deep key frame extraction method for sports training. The method is based on athlete skeleton extraction. As illustrated in Figure 2, the proposed frame extraction technique consists of four steps: preprocessing of the athlete training video, ROI extraction based on FCN, skeleton and feature extraction, and CNN-based key frame extraction. The proposed deep frame extraction method examines the poses of athletes in training videos. It first divides input videos into frame sequences followed by exploring ROI. FCN is applied for the extraction of foreground features of the athlete. Next, all the video frames are cropped according to the extracted ROI in the first frame.

3.2.2. Extracting Athletes' Skeletons. We used the ROI image extracted by the FCN network and the previously labeled ground truth to make the training data of the deep skeleton network. The original training image and the labeled ground truth are shown in Figure 3.

The Matlab (R2015a) software was used to extract the athletes' skeleton information of ground truth. The Matlab 'bwmorph' function was applied to perform the morphological operation on all images. The general syntax of Matlab bwmorp function is as follows:

BW2 = bwmorph (BW, operation, n), which applies morphological operation n times and n can be inf; in this case, the operation is repeated until the image no longer changes. Table 1 lists some of the different morphological operations that can be performed on images.

The different morphological operations can be selected to generate the athlete's skeleton information. The athlete's skeleton information of the four key postures is shown in Figure 4.

It can be seen from the athletes' skeleton information map that the four key postures have different athletes' skeleton information. The 373 labeled images were used to extract their athletes' skeleton information as the label of training deep skeleton network.

3.2.3. Generation of Athlete Skeleton Information. We prepared the training and test files, as shown in Figure 5. The left side represents the original image, whereas the right side is the ground truth.

Because the CNN network is changed from VGG (visual geometry group) network, some parameters of the VGG network are selected. The VGG is the conventional CNN architecture and consists of blocks, where each block consists of 2D convolution and max pooling layers. Similar to the FCN training method, the deep skeleton is different from the traditional single-label classification network but uses the image of athletes' skeleton information as the label.

After 20000 iterations, the trained model is obtained. The test set was randomly selected to test the recognition performance. According to the predicted value of each pixel, after normalization, the predicted gray image is drawn. The original and predicted images are shown in Figure 6.

The white portion in the figure indicates the skeleton information of athletes. The higher the value is, the more likely it is to be the skeleton information of athletes. Next, the nonmaximum suppression (NMS) algorithm is used to find the athletes' skeleton information. The NMS technique is used in several image processing tasks. It is a group of algorithms that chooses one entity out of many entities. We

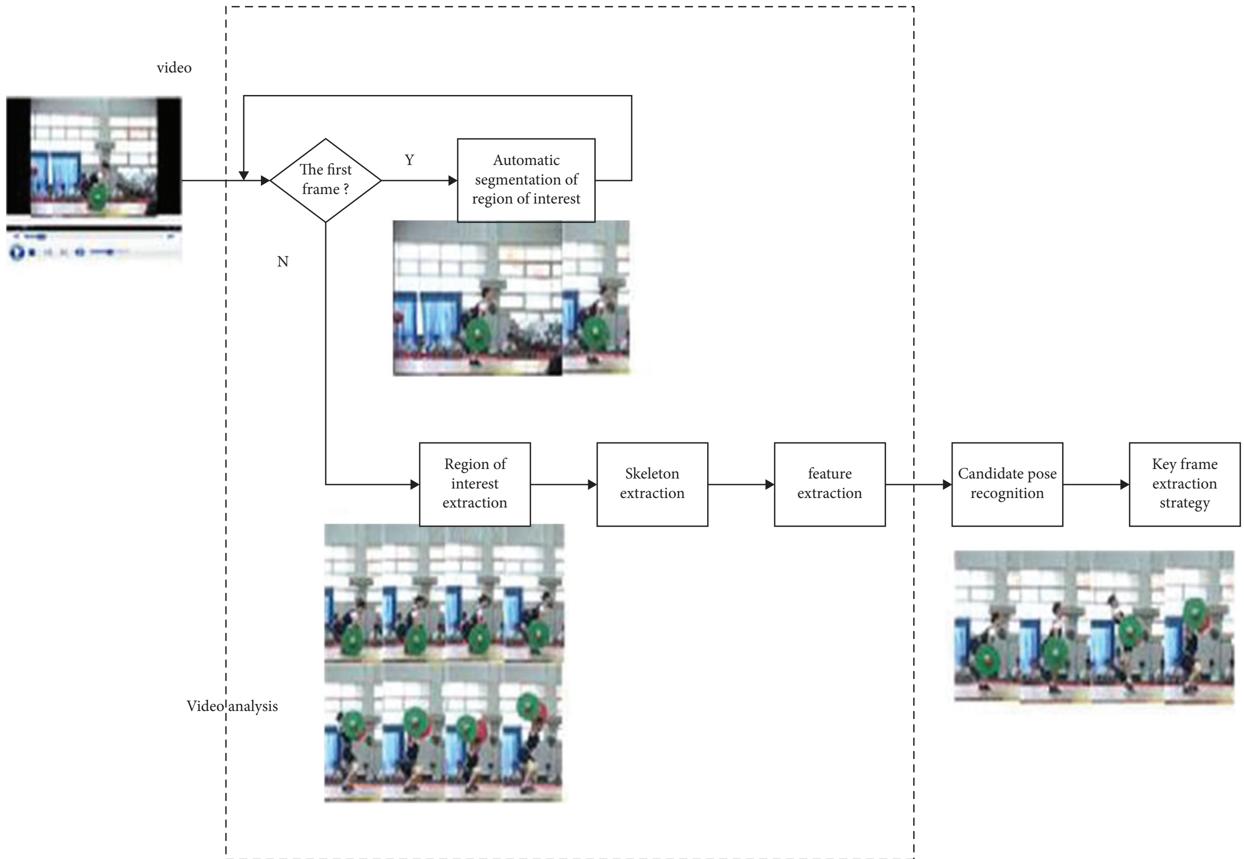


Figure 2: Algorithm framework.

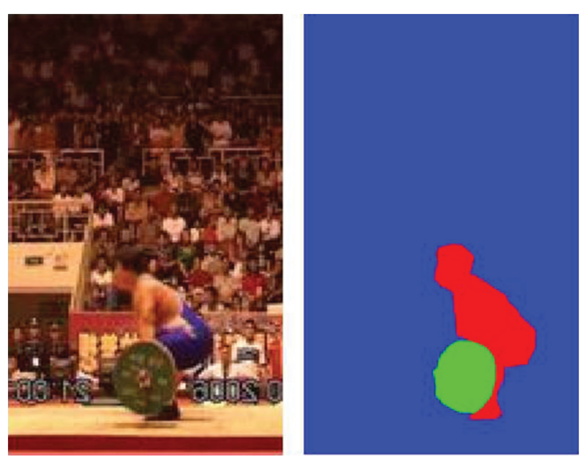
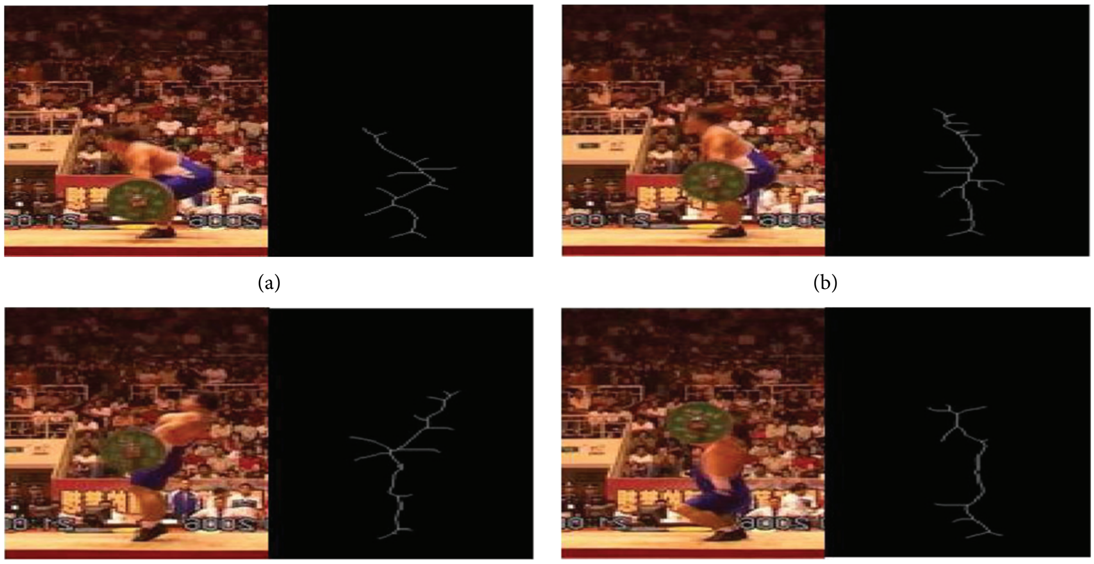


Figure 3: Original and ground truth.

Table 1: bwmorph morphological operations on images.

Operation	Description
Botha'	It is a morphological "bottom cap" transformation operation, and the returned image is the original image minus the morphological closing operation (closing operation: first expand and then corrode)
Bridge	Disconnected pixels: the value pixel is set to 1 if it has two nonzero unconnected (8 neighborhood) pixels
Clean	Remove isolated pixels (by O 1)
Close	Perform morphological closing operation (expansion before corrosion)
Diag	The diagonal filling is used to eliminate the 8 connected regions in the background
Dilate	The structure ones (3) are used to perform the expansion operation
Erode	The structure ones (3) are used to perform the corrosion operation
Fill	Fill in isolated internal pixels (0 surrounded by 1)



(a) (b) (c) (d)

Figure 4: (a) The original picture of athlete's and the ground truth of athletes' skeleton. (b) The original drawing of the knee lead and the ground truth of the athlete's skeleton. (c) The original drawing and the ground truth of the athlete's skeleton. (d) The original map of the highest point and the ground truth of the athlete's skeleton.

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Figure 5: Training parameter.

Figure 6: Original and predicted results.

take 3 neighborhoods as an example to introduce the implementation of the NMS algorithm.

NMS in three neighborhoods is to judge whether the element $I\ [x]$ $(2<=I<=W\text{-}1)$ of a dimension group $I\ [w]$ is greater than its left neighbor $I\ [I\text{-}1]$ and right neighbor $I\ [x+1]$ (Algorithm 1).

Lines 3–5 of the algorithm flow check whether the current element is greater than its left and right neighbor elements. If the condition is met, the element is the maximum point. For the maximum point $I\ [x]$, it is known that $I\ [x]>I\ [x+1]$, so there is no need to further process the $I+1$ position element. Instead, it directly jumps to the $I+2$ position, corresponding to the 12$^{\text{th}}$ line of the algorithm flow. If the element $I\ [x]$ does not meet the judgment condition of the third line of the algorithm flow, its right neighbor $I\ [x+1]$ is taken as the maximum candidate, corresponding to the seventh line of the algorithm flow. A monotonically increasing method is used to search the right until the element satisfying $I\ [x]>\mathrm{I}\ [x+1]$ is found. If $I<=W-1$, this point is the maximum point, corresponding to lines 10-11 of the algorithm flow.

We used the NMS method of MATLAB toolkit, according to the results of deep skeleton network output, and, finally, determined the information pixels that may be athletes' skeleton. The predicted results and NMS results are shown in Figure 7. The test effect picture including the athlete skeleton is shown in Figure 8.

```
(1) x = 2
(2) While I ≤ w−1 do
(3) If I [x]x > x I [x + 1] then
(4)     If I [x] >= I [x−1] then
(5)         Maximum At (x)
(6) Else
(7)     x = x + 1
(8)     While x ≤ w−1 AND I [x] <= I [x + 1] do
(9)     x = x + 1
(10)    If x ≤ w−1 then
(11)    Maximum At (x)
(12) I = x + 2
```

Algorithm 1: NMS for three neighborhoods.

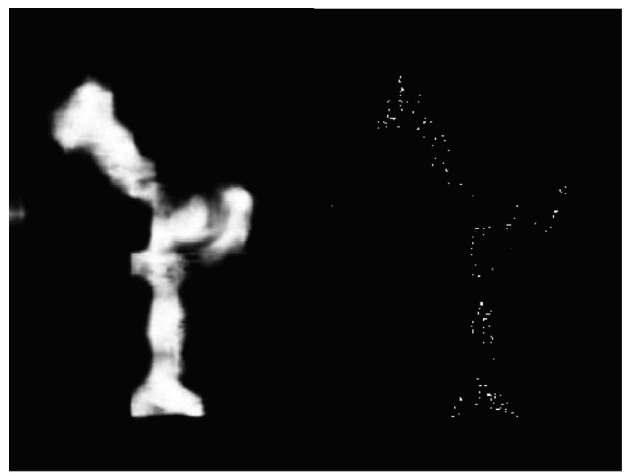

Figure 7: Prediction results and NMS results.

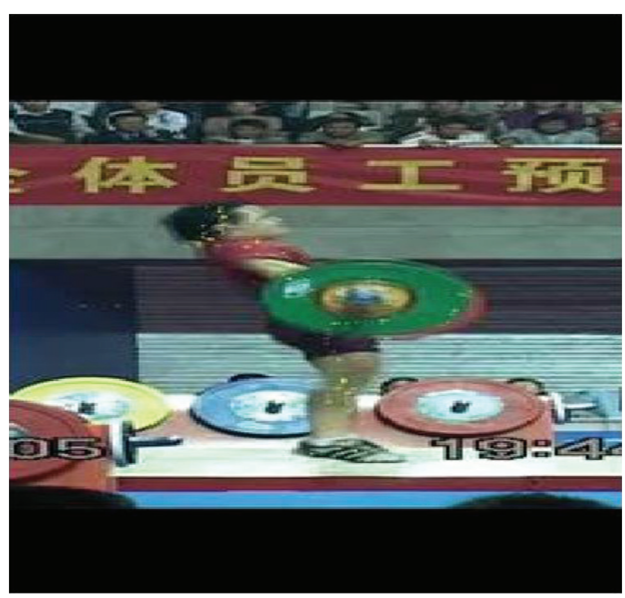

Figure 8: Test effect picture including athlete skeleton.

4. Results

In this section, we performed experimental analysis to confirm the performance of the proposed key frame extraction method. We performed experiments on sports videos collected from the Chinese Administration of Sports. All the videos contain four key athletes' poses.

4.1. CNN-Based Key Pose Estimation. The proposed key frame extraction method used CNN with ROI of the extracted video frames as input to predict probabilities of all poses. In all sports videos, there are four groups of key poses. The CNN model was used to calculate the probability of each frame for all frames estimated with accurate or inaccurate poses. Table 2 provides the classification results of 4 subjects corresponding to 4 poses of sport action videos. Firstly, 612 image frames are tested. Table 2 provides the number of correct and wrongly predicted frame number and the associated accuracy, sensitivity, and specificity for all poses predicted by CNN. It is evident that the accuracy, sensitivity, and specificity of pose probability estimated in the proposed model are higher than 90% on all the poses which provide a base for the ultimate key pose extraction in sports training.

4.2. Experimental Comparison. To ratify the superiority of the proposed key frame extraction method, we compared the obtained results with the existing pose estimation methods. The comparison results are shown in Table 3. Compared with the traditional deep learning method, the method in this paper has a great improvement. Because the athlete skeleton information is extracted from the key objects, the feature expression of human posture is enhanced, and the accuracy is improved. It can be observed that athletes'

Table 2: Test accuracy of four key frames.

	Total	Correct	Wrong	Accuracy (%)	Sensitivity (%)	Specificity (%)
Pose 1	169	166	3	98.2	92.4	94.7
Pose 2	130	125	5	96.1	90.4	95.3
Pose 3	155	152	3	98.1	96.3	98.3
Pose 4	158	155	3	98.1	97.6	97.7

Table 3: Experimental comparison.

Method	Accuracy (%)
Wu et al. [27]	90.6
Jian et al. [28]	97.4
Proposed skeleton-based method	**97.7**

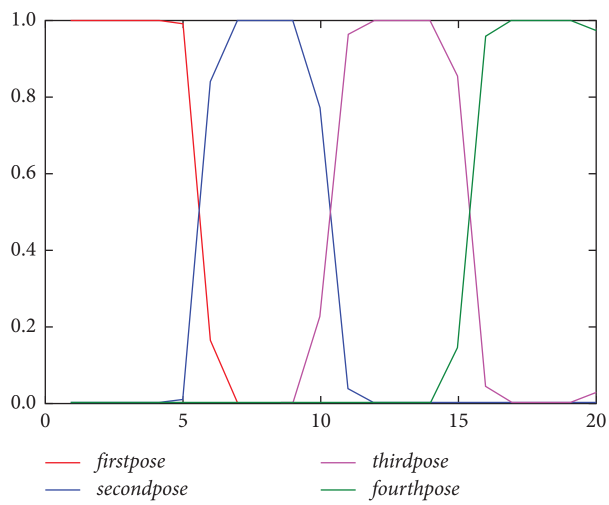

Figure 9: Test the results of the video.

skeleton extraction of key objects can improve the accuracy of classification. Wu et al. [27] achieved the highest accuracy of 90.6%, whereas Jian et al. [28] reported 97.4% accuracy. Compared with the aforementioned two methods, the proposed key frame extraction method achieved the highest average accuracy of 97.7% for all the pose categories.

4.3. Key Frame Extraction. Figure 9 shows the probability distribution of proposed skeleton-based key frame extraction for four groups of poses from training videos. It can be seen that the unique characteristics of each pose are properly captured, and the estimation of all four poses is good. In addition, the method in this paper has a very obvious performance in performance and effect and has a strong expression in each type of key posture. It combines FCN with CNN to extract ROI and distinct features and lays down the foundation for key frame extraction from sports videos. It further confirms that the proposed skeleton-based method conquers other key frame extraction methods. Test the results of the video is shown in Figure 9.

5. Conclusion

Object detection and behavior understanding in the video has become a point of contention in the field of machine vision. Sports video contains a lot of information related to the human movement which is complex and highly skilled. Compared with the analysis of human daily movements, the analysis and recognition movements in sports video are more challenging. In this study, we have presented a deep key frame extraction method for sport video analysis based on CNN. This paper extracts the key posture of athletes' training, to assist the coach to carry out more professional training for athletes, and puts forward a method to extract the skeleton information of human athletes. The human body in sports training action video is extracted through the skeleton of athletes to enhance the expression of features and the accuracy of key frame extraction. The experimental results and analysis validate that the proposed skeleton-based key frame extraction method outperforms its counterparts in key pose probability estimation and key pose extraction.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

Clustering Analysis of Risk Divergence of China Government's Debts

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It is a difficult time for the world's economics while the impact of COVID-19 is undergoing. A possible worldwide sovereign debt crisis could emerge, in short term, for supply chains blockage due to its slowing-down in many countries. China, having the second largest economy in the world, is crucial for the stability and sustainability of the economic recovery. China endures a long-term growth since 2000; nevertheless, a large amount of that growth is contributed by the government debt, which was spent on infrastructures. The accumulation of debts is a potential risk to the future growth of China. This research evaluates the central government and local government debts with a series of indicators. The weights of indicators are determined by objective methods of the CRITIC approach. Results confirm that the central government debt of China is on the edge of risk, while the risk of local governments debt is already in a concerning danger. The local government risk is 50% higher than the central government's risk. Moreover, the *K*-means clustering algorithm performed on data, collected from various provinces, suggests that the local government debts of China follow a pattern of geographical distribution; that is, the closer to the coast, the lesser the risk, which is in accordance with the pattern of labor flowing. Labors are attracted by job opportunities which lie in the well-developed regions of China. This is confirmed by the crosscheck with the wage growth data. This indicates that the less developed areas of China rely more heavily on debt-investment stimulation that could be of a potential stagnation because the yield of investment follows diminishing marginal returns and the relative lacking labor weakens the potential economic growth.

1. Introduction

Government debt has been a crucial factor in stability of governments and world economy. Usually when nations are not able to pay their debts, a particular nation would choose to "default" the debts if there is no more desperate action such as waging wars. Default on debt will drastically increase the borrowing costs because creditor requires higher interest rates to compensate the possibility of receiving nothing. The higher debt service costs will further decrease the nation's fiscal expenditure, especially in investments, which will crush the potential economic growth. That is what we observed in most debt crisis, such as the cases of Latin America and the 2008 sovereign debt turmoil in Europe. Furthermore, the debt crisis does not harm the default country, only, but the debt risk is contagious at regional level if it is not a global one [1].

China had enjoyed a long-term economic growth for the last decades. However, the potential growth rate of China becomes lower than 6% compared with the two-figure growth. From the second decade of 21st century, China depends on investments much more, and the large share of the investments is from the government (including local governments). Yet, the investment follows the law of diminishing returns, making investment less economic efficient. Thus, government debts start to accumulate fast. The government debt of China (including local governments) is more than 38 trillion Chinese Yuan. Comparing to the Gross Domestic Products (GDP) of about 100 trillion Yuan, the debt may not be an immediate and direct threat. The fast growth makes the debt risk a potential debt when the world economy was disrupted by the COVID-19 pandemic. Meanwhile, China now becomes the largest creditor in the world [2]. This suggests that the fiscal situation would decide the debt relief decisions on counties with heavy burden of debts.

Sovereign debt problem is not a new problem; from historical perspective, it is rare when there is no country to default their debts [3]. Though the foreign debt default usually causes international quarrel and conflict, the domestic debt's risk should not be underestimated [4]. Also when export takes a large share in nation's economic engine, the sovereign debt is vulnerable to international shocks [5]. For a large economic country like China, the foreign debt to total debt ratio is now much lower compared to the 1980s when the country requires immediate investment to stimulate the economic development. Note that China has gone through a certain economic transformation that significantly reduced their dependency on exporting, while the domestic consumption starts to rise.

The research about sovereign debt focuses on the risks it brought to other political and financial systems. While a market rich is in liquidity, stock market is easy to be endangered by the debt risk [6]. What follows is the bond market, which is directly linked with the government debt. Since most part of the government bond is traded in the domestic bond market, and based on the study about spreads of local currency bonds, the domestic debt risk is lower than foreign debts [7]. However, according to the study on Europe debt crisis, domestic banks of debt-stressed country would buy in more bonds that does not really ease the issue but buy more time for the nation to deal with the debt crisis [8]. Therefore, close risk monitoring and evaluation on the government debt is necessary. Mao et al. found that a debt crisis would transfer into a financial crisis, by the domestic commercial banks factor, as the debt crisis in Europe can be considered as an outcome of the 2008 financial crisis [9].

How to regulate the finance system is also an important topic discussed in the debt research. From the experience of Europe debt crisis, the right way would be setting more firewalls between the financial products. Research indicates that for the post-debt crisis in European counties, CDs and bonds in their markets have lower statistical cointegration [10]. Yet, the fundamental action would be reforming the fiscal situation. The mainstream of the field considers that the optimal fiscal policy would be procyclical actions [11]. Meanwhile, contractionary fiscal policy is also advocated by many researchers who believe high debt to the GDP ratio will force the interest rate to go up, based on the model study [12]. Moreover, Croce et al. [13] believe that cutting the balance of debt will increase the output and welfare level (2021). Nevertheless, in general, scholars are aware of incoming debt crisis. They call for more rigid fiscal rules while many economies are disrupted by the COVID-19 pandemic [14]. Afterall, both the procyclical and anticyclical fiscal policies require rigorous reviews and carry-outs. This research is an investigation of the China governments debts including both the central and the local. Methods such as K-means clustering are used on real datasets to obtain certain findings. Following are the major contributions of the research conducted in this paper:

(1) We evaluate the debt risks for both the central government and local government of China

(2) The methods of evaluation; that is, K-means clustering is implemented over real datasets to obtain certain findings

(3) We conclude that the central government debt of China is on the edge of risk, while the risk of local governments debt is already in a danger

(4) The local government risk is 50% higher than the central government's risk; and the local government debts of China follow a pattern of geographical distribution

The structure of the remaining part of this paper is as follows. Section 2 describes the details of the research methodology. In Section 3, we discuss the outcomes of our results that are based on a clustering method, that is, K-mean clustering approach. Section 4 describes our research findings. Finally, Section 5 concludes this paper along with several directions for future research.

2. Research Methodology

Various risk indicators are used to reach an accurate and precise evaluation. Below we describe different indicators both for local and central governments and how these indicators are computed, and what kind of risk they reflect. At last, we describe the K-means clustering technique, briefly.

2.1. Central Government Indicators. The central government debt risk can be divided into 6 risk indicators from (R_{11} to R_{16}) to reach an accurate and precise evaluation. Below are how these indicators organized, and what kind of risk they reflect. R_{11} is calculated by dividing the fiscal deficit to GDP, which evaluates the fiscal deficit's share in the overall economic activity of a year. That also can be interpretated as how much a nation's economic relies on financial deficit. For this indicator, a lower value means a lower risk. R_{12} is bond issuing volume divides fiscal expenditure, evaluating how much a government's expenditure relies on borrowing. Also, the lower is the better. Usually, the benchmark of R_{12} is set to 25%. However, considering the bonds of China local governments are endorsed by the central government (the market and everybody strongly believe so), the central government bond issuing volume to fiscal expenditure ratio R_{12} is set to 15%. For local governments, the same risk indicators will be evaluated using R_{12}. R_{13} checks the pressure from debt service, by dividing the debt service with fiscal income. The higher the R_{13}, the higher the risk, because the government must use a larger share of their income to pay debts and interests.

R_{14} is constructed in the same manner as R_{11}, which is the ratio of bond issuing volume to GDP, which represents how much the economic running relies on the government borrowing of a year. The lower is the better, as well. According to the rule of thumb, the benchmark line is set on 3%. There is no strict theoretical explanation about that number. Researchers and studies choose the "3%" that could be influenced by the "Treaty of Maastricht" from Europe. The Treaty established economic and fiscal standards for those countries wish to join the European Union (EU). For instance, a country cannot have a high inflation rate and a fiscal deficit higher than 3% of their GDP. Although, since 2008, China started to enact proactive fiscal policies, their R_{14} are well controlled by under 3% (the benchmark was breached for only two times). Meanwhile, many major nations have higher rates than 3%. Considering the impact of the COVID-19 pandemic, many nations rely on the borrowing much more than before. The benchmark of R_{14} still sticks to 3%.

R_{15} is constructed by dividing bond issuing volume with deposits outstanding. Government bond is a kind of borrowing; thus, creditors who provide cash funding are required for the equation. Deposits outstanding is the money which can purchase bonds. A low R_{15} ratio indicates more money is available to do the purchase. Though the interest rates can evaluate the money shortage level, their rapid fluctuations make it difficult to be a reliable indicator. The interest rates are influenced by many other markets such as stock and real estates. The bond issuing volume to deposits outstanding ratio is a more objective indicator to reflect the risk of borrowing. Furthermore, R_{16} is a crucial indicator measuring the balance of a nation debt to its GDP. For developed countries, currently their R_{16} are way ahead of 100% or even higher. For instance, since Japan's bubble economy burst in late 1980s, the Japanese government relied highly on borrowing (yet the stimulation effect was not so satisfying). The GDP per capita stays still for a long while; thus, the saying of "the lost decade/decades" arose. Nowadays, the debt to the GDP ratio of Japan is larger than 270%, which reflects that R_{16} is a significant indicator (refer to Table 1 for various indicators).

The GDP or R_{16} ratio is also an important fiscal criterion of joining the EU, by setting the benchmark as 60%. In this research, the benchmark is lift to 70%, because the nations around the world have higher debt to GDP ratios than a decade ago. For instance, the United States now reaches 128%. Similarly, the foreign debt to GDP ratio of Japan is over 92%. Traditional developed countries in Europe also suffer from high debt level: Germany 78%, Netherlands 75%, UK 102%, France 114%, Spain 118%, Italy 160%, Belgium 122%, and Greece (which been criticized a lot by EU countries) 213%. Meanwhile, a promising country that attract many foreign companies to set their headquarters, Ireland, also has a high debt ratio of 90%. It can be concluded that the benchmark set by EU has been penetrated by almost all EU nations. Therefore, in this research, we lift the benchmark value of R_{16} to 70%, which will not underestimate the potential risk, for China that has a much lower debt ratio. Considering the international financial market is functioning well so far, the portfolios will invest more on Chinese government bonds while others are too risky. The central government debt risk indicators are shown in Table 1.

2.2. Local Government Indicators. The indicators introduced above in Section 2.1 sum up the central government debt risk evaluation. They are organized into Table 1. For the local government debt risk, the indicators are constructed in the same manner with the central government evaluation. R_{21} to R_{24} are identical with R_{11} to R_{14}, while R_{25} is constructed in the same way as R_{16}. They are highlighted in Table 2.

2.3. The CRITIC Method. As shown in Tables 1 and 2, all indicators have their own weights. That was calculated by the CRITIC method (Criteria Importance Through Intercriteria Correlation), which can handle the issuance of indicators having the same elements efficiently. For $R_{11,}$ $R_{14,}$ and R_{16}, they have the same element of GDP. Thus, GDP has influence on the values of these indicators. That is why CRITIC was introduced because it can measure information entropies (while evaluating the level of correlations) and calculates the redundancy of indicators. So, when few indicators are correlated on a certain level (making them provide less information), their weights will be trimmed in CRITIC method. Again, $R_{11,}$ $R_{14,}$ and R_{16} all have the elements of GDP, but they also evaluate the fiscal deficit, bond issuing volume, and debt balance, which implies that these indicators cannot be further simplified. By introducing CRITIC, the problem of correlated indicators can be balanced, and the final weights can be well balanced with the objective. Below are how weights calculated by the CRITIC method [15].

Say there are n samples, and each sample is regulated by p indicators and that can be denoted as a matrix A in equation (1), where u_{ij} is the indicator value of number j (of the sample i).

$$A = \begin{vmatrix} u_{11} & u_{12} & \cdots & u_{1p} \\ u_{21} & u_{22} & \cdots & u_{2p} \\ \cdots & \cdots & \cdots & \cdots \\ u_{n1} & u_{n2} & \cdots & u_{np} \end{vmatrix}. \tag{1}$$

All indicators need to be nondimensionalized by Max-best or Min-best (larger value the better or less value the better). Considering this research focus on risk evaluation with the indicators introduced in Tables 1 and 2, indicator value should be handled with Min-best by equation (2). For simplicity, u_{ij}' after equation (2) will still be denoted as u_{ij}.

$$u_{ij}' = \frac{u_{\max} - u_j}{u_{\max} - u_{\min}}, \quad (j = 1, 2, \ldots, N). \tag{2}$$

Then, the standard deviations of indicators S_j need to be evaluated by the following equation, while $\overline{u_j} = 1/n \sum_{i=1}^{n} u_{ij}$.

$$S_j = \sqrt{\frac{\sum_{i=1}^{n} \left(u_{ij} - \overline{u_j}\right)^2}{n-1}}. \tag{3}$$

The conflicts of indicators R_j need to be calculated by equation (4), while r_{ij} is the correlation coefficient between indicator i and j. The larger the r_{ij}, the more redundance in indicators i and j, which means they provide less information. And their weight should be less in the overall indicators.

$$R_j = \sum_{i=1}^{p} \left(1 - r_{ij}\right). \tag{4}$$

Table 1: The central government debt risk indicators.

Indicators	Definitions	Weights	Benchmark (%)
R_{11}	Fiscal deficit/GDP	0.188	3
R_{12}	Bond issuing volume/fiscal expenditure	0.128	15
R_{13}	Debt service/fiscal income	0.252	8
R_{14}	Bond issuing volume/GDP	0.114	3
R_{15}	Bond issuing volume/deposits outstanding	0.130	4.8
R_{16}	Balance of national debt/GDP	0.188	70

Table 2: The local government debt risk indicators.

Indicators	Definitions	Weights	Benchmark (%)
R_{21}	Fiscal deficit/GDP	0.121	3
R_{22}	Bond issuing volume/fiscal expenditure	0.290	15
R_{23}	Debt service/fiscal income	0.135	8
R_{24}	Bond issuing volume/GDP	0.198	3
R_{25}	Balance of local government debt/GDP	0.257	70

The information entropies C_j are calculated by the following equation, that $C_j = S_j \times R_j$. And the final weights of indicators are generated by equation (6).

$$C_j = S_j \sum_{i=1}^{p} \left(1 - r_{ij}\right), \tag{5}$$

$$W_j = \frac{C_j}{\sum_{j=1}^{p} C_j}. \tag{6}$$

Above we briefly summarized how the weights for various indicators, as shown in Tables 1 and 2, are calculated.

2.4. K-Means Clustering Method. Before entering to the discussion of actual results, the analysis method of K-means needs to be introduced for risk evaluation in China local governments, to reach a detailed investigation on the risk differences of Chinese provinces. There are two advantages of applying the K-means clustering approach. First, it is an efficient clustering algorithm. Secondly, when the clusters are highly dense with nonsignificant differences, K-means can produce well clustering results. Below are how clusters are determined by K-means method [16].

For a dataset $X = \{x_1, x_2, x_3, \ldots, x_n\}$, there are n d-dimensional data point, while $x_i \in R_d$. The goal is to make the data into K clusters. In the first, the algorithm will divide the dataset into K subsets, $C = \{c_i, i = 1, 2, \ldots, K\}$. Each subset has a clustering center u_i. Then, $J(c_k)$ is the sum of the data points distances from the center defined in equation (7), which is calculated by the Euclidean distance.

$$J(c_k) = \sum_{x \in c_k} x_i - u_k^2. \tag{7}$$

The overall goal is to minimize the sum of all $J(c_k)$ in equation (8), which is $J(C) = \sum_{k=1}^{k} c_k$.

$$\begin{aligned} J(C) &= \sum_{k=1}^{k} c_k, \\ &= \sum_{k=1}^{k} c_k \sum_{x \in c_k} x_i - u_k^2 \\ &= \sum_{k=1}^{k} \sum_{i=1}^{n} d_{ki} x_i - u_k^2 \end{aligned} \tag{8}$$

where $d_{ki} = \begin{cases} 1 & x_i \in c_i \\ 0 & x_i \notin c_i \end{cases}$ in equation (8) and the mean square error E is used for evaluation in equation (9). In equation (9), p is the data point while m_1 is the clustering center of the cluster c_1.

$$E = \sum_{i=1}^{k} \sum_{p \in c_1} \left(\left|p - m_1\right|\right)^2. \tag{9}$$

The actual K-means clustering algorithm starts with a dataset of n points. Then, randomly choose k points for clustering centers $m_i\,(i = 1, 2, 3, \ldots, k)$, following by calculating each point p to its center's distance $d(p, m_i)$, and that is defined in equation (10), where $i = \{x_{i1}, x_{i2}, \ldots, x_{\text{in}}\}$ and $j = \{j_{i1}, j_{i2}, \ldots, j_{\text{in}}\}$ are n-dimensional data.

$$d(i, j) = \sqrt{\left(x_{i1} - x_{j1}\right)^2 + \left(x_{i2} - x_{j2}\right)^2 + \cdots + \left(x_{\text{in}} - x_{jn}\right)^2} \tag{10}$$

For each point p, it will go through distance calculations for each cluster, the minimum distance $d(p, m_i)$ will decide which cluster p belongs to. After all points have been evaluated, cluster centers m_i will be recalculated by equation (11), where m_k is the Kth cluster and N is the number of data points in the cluster K.

$$m_k = \frac{\left(\sum_{i=1}^{N} x_i\right)}{N}. \tag{11}$$

Data points will be assigned to the most similar clusters. The process will iterate until E of equation (9) ceases to decrease, which indicates an optimized clustering has been achieved.

3. Results and Outcomes

For the central government's debt risk, the R_{11} to R_{16} indicators are calculated and organized in Table 3. These outcomes are based on the data from the National Bureau of Statistics and Ministry of Finance, China. The data being

Table 3: The values of the central government debt risk indicators.

Time	R_{11}	R_{12}	R_{13}	R_{14}	R_{15}	R_{16}
2019	1.63	2.34	0.55	1.06	0.90	0.24
2018	1.36	2.33	0.50	1.05	0.90	0.23
2017	1.23	2.70	0.45	1.24	1.04	0.23
2016	1.26	3.19	0.40	1.51	1.24	0.23
2015	1.14	2.21	0.29	1.06	0.89	0.22
2014	0.59	0.93	0.32	0.41	0.39	0.21
2013	0.14	0.02	0.03	0.02	0.15	0.21
2012	0.54	0.86	0.28	0.37	0.37	0.21
2011	0.37	1.04	0.29	0.44	0.44	0.21
2010	0.55	1.47	0.28	0.60	0.57	0.23

investigated begins from year 2010 to 2019. The end-date is before the outbreak of the COVID-19 pandemic, which could provide results without the economic impacts of the COVID-19 outbreak both in China and the rest of the world. The impact of COVID-19 will be discussed in Section 4. For risk indicators and their results which are calculated, it is essential that the meaning of these values needs to be elaborated. For R_{16}, it is the ratio of balance of national debt to GDP, and the benchmark is 70%. Take the R_{16} of 2019, for example, its value is 0.17. Thus, the R_{16} risk is $0.17/0.7 = 0.24$, which is not an abrupt threat while the weighted risk is $0.24 * 0.257 = 0.109$.

About the risk value of indicators (before weighted), the value of 0.8 to 1 can be interpreted as the risk (represented by the indicator) is now exposed in danger. Moreover, the risk value between 0.5 and 0.8 can be concluded as median threat, meaning that the risk is about to cause problems and need to be handled using careful measures. The value between 0.2 and 0.5 is a minor threat, which requires some sort of intervenes. Moreover, 0 to 0.2 can be considered as risk free, and no immediate actions are required except observation and monitoring. The overall risk of the national government risk is interpreted in the same fashion as the risk indicator above. The values of the national debt's risk indicators are presented in Table 3. The overall national debt (and weighted risk indicators) risk values are organized in Table 4.Source: Data organized from the National Bureau of Statistics of China.

For the local government debt risks, each province's indicators from R_{21} to R_{25} are calculated in the same manner as the nation debt risks analysis. However, the results of every province will be too much to discuss and present here. Therefore, only the overall debt risks (from years 2015 to 2019) of each province are demonstrated in Table 5. According to the risk levels, these provinces are clustered by the K-means method (with $K = 5$) to reach a better understanding of the geographical distribution pattern about the government debt risk. One more thing about the data of local government debts needs to be explained, that the data started from 2015 rather from earlier. It is because that the local government debt was not in the form of local government bonds, which makes it difficult to estimate the overall balance of debt. The data from 2015 onwards would be more precise, because at that time the local governments debts (and previous debts with all kinds of forms) were already reviewed and available in the forms of bonds. The debt risks of the local governments and their clustering, using the K-means method, are shown in Table 6.

4. Discussion

According to the results, as shown in Table 4, the overall national debt risk has a clear increase in 2015. From 2010 to 2014, the risk stabilizes in the interval from 0.4 to 0.5. Within two years, the risks value doubled and reaches 1, which is exposed to immediate danger. The weighted values of national debt's major indicators are shown in Figure 1. The changes of risk indicators values would reveal the core threats. The major contributor of the national debt risk is R_{12}. It rises from 0.1 to 0.3 from 2014 to 2016, which indicates the government relies on debt much more than the maintained daily functioning. Also, R_{11} shares the same pattern, indicating the fiscal deficit to GDP ratio grows rapidly. However, R_{16} remains at a low and safe level. The balance of debt to GDP keeps around 30%, providing a certain room for future borrowing. Comparing with major developed countries' R_{16} (more than 100%), China has a much lower risk which would attract domestic and foreign investors to the Chinese government bonds that may buy more time for China to modify its debt structure.

For the local governments of China, the risk is much more severe. Figure 2 shows the debt risks of all provinces according to the result in Table 5. It can be found out that most local governments are in debt risk danger, in particular, those having the risk value larger than 1.

The overall local governments' debt risk is the sum of all the provinces' weighted risk values. The weights of provinces are determined by their shares in the national GDP. The local government's overall debt risk starts at 1.3 in 2015; then, in 2016, it grows to a dangerous level of 1.8. Then, it drops down fast in 2017 and has stabilized at 1.5 in recent years. However, the risk shows with a strong upward trend, indicating that the local governments are in trouble of debt, and it is difficult to turn the flow. It may require more investment on infrastructures of poor provinces to stimulate the economy but that means more funding will be needed, especially when most provinces are already in deficit and rely on borrowing.

For provinces of the first cluster in Table 1, their average risk values are around 1, which indicate they are already exposed to danger. For them, further monitoring is required.

Table 4: The overall risk of the central government and weighted risk indicators.

Time	Overall	R_{11}	R_{12}	R_{13}	R_{14}	R_{15}	R_{16}
2019	1.029	0.306	0.299	0.140	0.120	0.118	0.046
2018	0.962	0.256	0.298	0.127	0.120	0.118	0.044
2017	1.012	0.231	0.345	0.115	0.141	0.136	0.044
2016	1.123	0.237	0.409	0.100	0.172	0.162	0.043
2015	0.849	0.214	0.283	0.073	0.121	0.116	0.042
2014	0.447	0.111	0.119	0.081	0.047	0.050	0.040
2013	0.455	0.116	0.123	0.075	0.049	0.052	0.039
2012	0.411	0.101	0.110	0.071	0.043	0.048	0.039
2011	0.422	0.069	0.134	0.072	0.050	0.057	0.040
2010	0.548	0.103	0.188	0.070	0.068	0.075	0.044

Table 5: The wages growths of provinces compared to the average.

Wage growth from 2006 to 2019			
Zhejiang	−0.71	Gansu	0.01
Guangdong	−0.58	Guangxi	0.03
Liaoning	−0.56	Inner Mongolia	0.06
Shanxi	−0.49	Hebei	0.11
Tianjin	−0.42	Xinjiang	0.16
Shanghai	−0.35	Anhui	0.16
Henan	−0.32	Jilin	0.18
Ningxia	−0.31	Chongqing	0.19
Tibet	−0.27	Shaanxi	0.38
Jiangsu	−0.25	Sichuan	0.41
Qinghai	−0.19	Yunnan	0.41
Beijing	−0.12	Jiangxi	0.47
Fujian	−0.11	Hubei	0.70
Shandong	−0.07	Guizhou	0.73
Hunan	−0.06	Hainan	0.86
Heilongjiang	−0.02		

Following is the second cluster with average risk value of 1.3. These provinces are in debt trouble and only their strong financial and economical actions could turn the flow. Particularly, for Tianjin, its value jumps up fast from 0.7 to 1.9 in less than five years and the situation could go worse. Then, clusters 3 and 4 have rather high average risk values, which is more than 2. It can be considered that these local provinces cannot drive them out of the debt mire on their own (neither further borrowing nor economic measures), especially for the Guizhou, Qinghai, and Tibet. However, the situation is not that severe, because these provinces have much lower population as compared to other regions, making the bailout actions from the central government possible and affordable. Meanwhile, Guizhou's debt issue is improving because Guizhou uses its geographical advantages (high attitude with low temperature) well to attract cloud-computing industry to invest. The future finance of Guizhou would perform better with more tax income.

The debt risk of the local governments shows a strong geographical pattern. The provinces with the lowest risk lie in the east coast of China, while provinces in the second cluster (except Tianjin) lie in the middle region. Similarly, the provinces in the third cluster (except Guangxi) are all in the west and north-east regions. The debt risk of the local governments becomes lower from the west to the east of China. The pattern is on account of the provinces on the coast endures a long term of investment due to their conveniency of transportation and supply chain, which booms the economy. Moreover, the study on China population mobility data also records this trend [17]. A better economic efficiency allows government borrowing can turn into high-quality future income. This may ease the accumulation of the local government debts. The provinces in the middle and the west have not the same financial boost as the east provinces in the past. This is similar to the conclusion of the research on less developed countries in the EU, which suffer more from the debt problem [18]. Yet, it is not the reason to stop or cut down the relatively poor provinces' borrowing. The structural economic problem needs to be tackled to ensure a balanced development around the country.

One important problem is the divergence of wage around the provinces. Table 5 lists the wage changes compared to the average changes. For instance, Zhejiang's wage growth compared to average change is −0.71, which indicates the wage in Zhejiang province grows slower than other provinces. Moreover, a slower wage growth provides a comparative advantage in the economic growth, which is reflecting in the potential risks of the local government debts. This means better job opportunities and population inflow in the province. The results of other provinces in the table can also be interpreted in the same manner.Source: Data organized from the National Bureau of Statistics of China.

Table 6: The debt risks of the local governments and their clustering.

	Average	2019	2018	2017	2016	2015	Cluster
Guangdong	0.706	0.640	0.702	0.598	0.984	0.607	1
Shanghai	0.823	0.835	0.558	0.574	1.273	0.872	1
Beijing	0.887	1.002	0.649	0.832	0.944	1.008	1
Shandong	1.108	1.200	1.076	0.927	1.450	0.890	1
Jiangsu	1.121	1.097	1.014	0.964	1.432	1.099	1
Zhejiang	1.154	1.068	0.907	0.847	1.722	1.227	1
Fujian	1.181	0.936	0.884	1.279	1.567	1.238	1
Henan	1.302	1.365	1.181	1.374	1.397	1.195	2
Shanxi	1.395	1.397	1.278	1.384	1.583	1.331	2
Tianjin	1.444	1.903	1.617	1.148	1.793	0.760	2
Hubei	1.446	1.648	1.203	1.158	1.887	1.336	2
Jiangxi	1.500	1.574	1.481	1.537	1.478	1.428	2
Chongqing	1.575	1.743	1.420	1.603	1.854	1.257	2
Anhui	1.617	1.519	1.827	1.519	1.703	1.515	2
Hebei	1.644	1.967	1.847	1.320	1.772	1.313	2
Sichuan	1.788	1.834	1.728	1.860	2.000	1.516	3
Liaoning	1.843	1.867	1.726	1.778	2.339	1.504	3
Shaanxi	1.844	2.015	1.737	1.612	2.257	1.600	3
Hunan	1.921	2.405	1.771	1.650	2.424	1.353	3
Jilin	1.960	2.264	2.176	2.053	1.761	1.548	3
Guangxi	2.048	1.998	2.251	2.315	2.048	1.626	3
Heilongjiang	2.191	2.519	2.785	1.949	2.039	1.661	3
Inner Mongolia	2.245	2.275	2.158	2.146	2.759	1.889	3
Xinjiang	2.375	2.428	2.356	2.476	2.583	2.031	4
Hainan	2.525	2.542	2.651	2.708	2.895	1.829	4
Yunnan	2.604	2.341	2.420	2.758	2.961	2.541	4
Gansu	2.737	3.004	2.769	2.680	2.769	2.461	4
Ningxia	2.771	3.062	3.062	2.476	2.786	2.468	4
Guizhou	3.498	2.949	3.520	3.239	3.932	3.849	4
Qinghai	4.651	5.138	4.908	4.679	4.619	3.910	4
Tibet	6.649	6.800	6.265	6.573	6.842	6.766	4

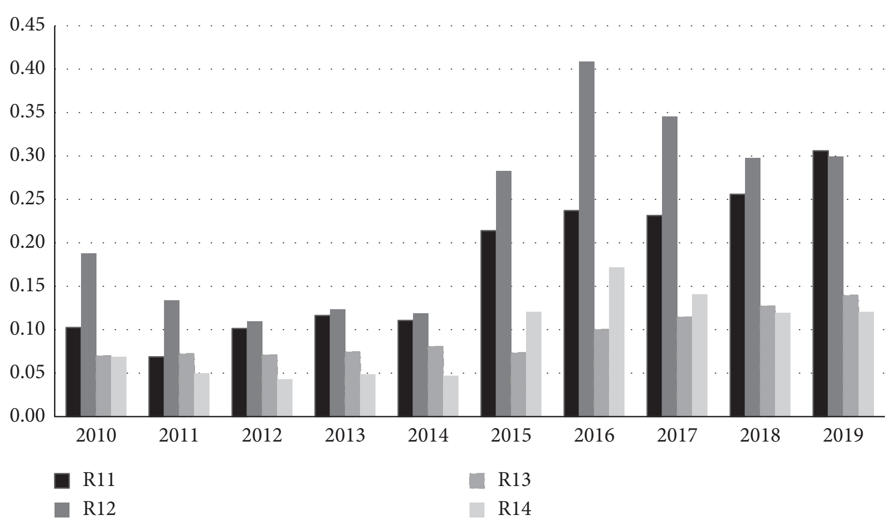

Figure 1: The weighted value of national debt's major indicators.

For the provinces having the lowest debt risks (cluster 1), their wage growth is slower with an average of 0.315, while the figure of provinces in clusters 2 and 3 is around 0.05 which is slightly higher than the average level. The provinces in clusters 4 have a faster wage growth of 0.175. The wage divergence of provinces correlates with the debt risks. Mobility and relocation of population result in wage divergence, which eventually reshape the economicperformances of different regions. To ensure a balanced development and control the debt risk, the factor of wage and population needs to be investigated further.

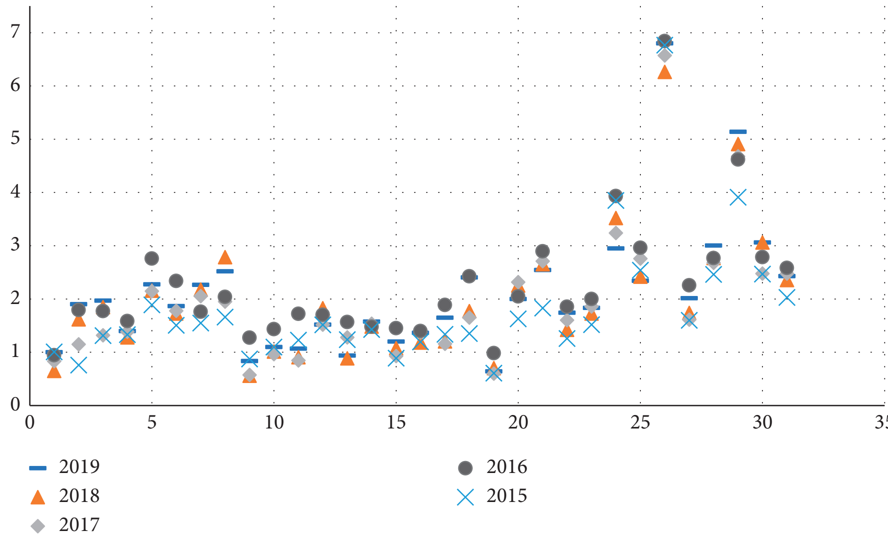

Figure 2: The debt risk values of the local governments.

5. Conclusions and Future Work

This research investigates the current situation of the debt risk problem, covering both the national government and local governments of China. At this moment, COVID-19 has been spread over the world for two years, strongly disrupting the world economy. The IMF and other institutions concern the potential impacts of sovereign debt crisis and have raised the warning line of debt to GDP ratio as 90%, which we believe may ease or conciliate the market to prevent government bonds' panic selling. Assuming the world's economy will not reach a pleasing level in the short term, sovereign debt risk requires close attention to prevent an upcoming potential debt crisis like Europe in 2018. We evaluated the risk of the central government of China showing that the risk has an increasing trend and reaches the critical level. However, China carried out many direct fiscal expenditures cuts, which is affective to cover the risk. Moreover, the debt to GDP ratio is still on low level as compared to developed countries, which buys more time for China to deal with debt problems. We estimated that the nation debt is not facing immediate threat or risk. According to the general opinion, the debt to GDP ratio does not have to be kept on a low level [19].

For the local governments of China, our evaluations indicated that almost all provinces breached the critical level of debt risk. Few well-developed provinces are free from urgent risk while other rely on borrowing to maintain the debt services. Furthermore, they depend on Beijing funds, making them less willing to improve their fiscal situations [20, 21]. Due to fiscal transfer payment system, the Beijing fund is considered a rich resource and the local bodies get used to "sleep on," which increases economical welfare [22]. As the risk evaluation indicated, the overall debt will accumulate until the central government can no longer cover. Assuming that the central government is on good position about borrowing, debt risks of local bodies can be handled with right moves. In 2021, the central bank of China tightened the money supply to inefficient industries that is a good start to turn the flow. We observed that the debt risk divergence of the local governments matches the wage divergence—most like the studies on Europe debt crisis. Future research will focus on actual actions for China's balanced development policy. By filling the economic gap of provinces, the population mobility situation and wage divergence would certainly change, which could alter the trend of the local debt risks.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study.

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Research Article

An English Network Teaching Method Supported by Artificial Intelligence Technology and WBIETS System

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The traditional English teaching system has certain problems in the acquisition of teaching resources and the innovation of teaching models. In order to improve the effect of subsequent English online teaching, this paper improves the machine learning algorithm to make it a core algorithm that can be used by artificial intelligence systems. Moreover, this paper combines the WBIETS system to expand the system function, analyzes the needs of the English network teaching system, and constructs the system function modules and logical structure. The data layer, logic layer, and presentation layer in the system constructed in this paper are independent of each other and can be effectively expanded when subsequent requirements change. In addition, this paper solves the problem of acquiring English teaching resources through the WBIETS system. To evaluate the performance of the English network teaching system, this paper performs comprehensive mathematical and experimental analysis. The experimental results show that the system constructed in this paper basically meets the actual teaching requirements.

1. Introduction

English is compulsory for education around the globe and a mandatory course in most universities. In the past two years, due to COVID-19, most of the on-site English teaching has transformed to online teaching, but traditional online teaching faces certain challenges that hinder its widespread adoption. Based on these challenges and shortcomings, this paper analyzes the traditional English network teaching system and combines artificial intelligence technology and the WBIETS system to construct an English network teaching system. With the deepening of online education, educational sponsors and students have reflected more profound problems [1]. After starting the course, the problem of how to quickly and accurately find the required resources has become increasingly prominent that has raised new questions for the development of Internet education platforms [2].

The online education system is a system platform established to express educational content and implement educational activities through the Internet. On the Internet teaching platform, teachers can answer questions online. These functions make a great contribution to traditional educational activities. However, with the long-term operation of the system, the unreasonable structure of the website has been exposed. Moreover, in the process of students' self-learning, there are problems such as being unable to face a large amount of information [3]. In the use of the system, many user access logs are stored on the website. The major contributions of this work are as follows:

(1) Through the WBETS mining analysis of these log records, the user's access patterns are discovered and analyzed.
(2) Moreover, useful user action patterns are applied to website structure adjustment and page push services. When users with similar characteristics visit the website again, they are pushed to the relevant network resources to realize the personalized and humanized services of the website.

The rest of this paper is organized as follows. In Section 2, the related works from the literature are provided. In Section 3, the algorithmic analysis of the English network teaching system is discussed. In Section 4, the construction and performance analysis of the English network teaching system based on artificial intelligence and the WBIETS system are elaborated. Finally, we conclude the paper and future research directions are provided in Section 5.

2. Related Works

For technical research and development of a smart education system, the researchers used the open source software of smart education to develop their own new functions based on the existing design. The design of online course resources involves teachers integrating their own courses into the platform of wisdom education, increasing the educational resources of the teaching plan and various educational activities, and applying them to actual teaching to allow teachers to experience guidance [4]. Educational design based on wisdom education involves various links and factors in education, such as analyzing the educational objectives of the curriculum, the weight of the curriculum, students, learning content, educational methods, learning activity design, learning evaluation, and other links [5].

Wisdom educational knowledge management has functions and characteristics, which can realize personal knowledge management and play an important role in education. Through the smart education system, teachers organize the knowledge and experience of education courses into a network platform and provide them to learners. After that, learners can manage their own knowledge while learning it [6]. Online education provides learners with an educational platform through the intelligent education system to improve their learning ability. Moreover, it uses the online learning of the intelligent education system to train teachers and students. The system evaluation of smart education includes the comparison of the advantages and disadvantages of the smart education system and other online education systems, its functional characteristics and the evaluation of each module, and complete recommendations [7]. At present, smart education mostly focuses on theoretical research and evaluation but lacks the analysis of data in the education system and the applied research that actually enters education. In addition, in higher vocational colleges, the application of intelligent education network education system is less popular, and educational resources need to be developed and integrated, and there is a lack of many excellent demonstration courses [8].

In [9], it was proposed that the structured system should be free to choose the content which is of interest to learners and then provide suggestions and guidance to students according to the actual situation. The system designed in [10] has functional modules related to the evaluation of learners' behavior. The system design proposed in [11] is mainly composed of learners' discovery of learning goals, learning behaviors, and personalized learning. In [12], the authors analyzed learners for individual learning and promoted the transmission of learning resources. In [13], the authors developed a course signal project to judge the current academic performance of students through the student information system, content management system, and student scores.

From the above analysis, the current research of experts and scholars on online teaching is mostly focused on pushing resources and the reproduction of traditional teaching models in online teaching, which is not good for modern English teaching. To address the aforementioned shortcoming, this paper uses artificial intelligence algorithms to create an innovative construction of English network teaching system.

3. Algorithmic Analysis of English Network Teaching System

The number of layers of deep neural network (DN) determines the ability to fit complex functions. The DN uses back-propagation to solve the problem of local optimal solution of optimization function. However, the upper neuron in the DN structure can form connections, the signal direction of neuron propagation is fixed, each time point is relatively independent, and it cannot work according to changes in time series. The chronological order of the text sequence is very important for natural language processing applications [14].

This paper improves on the extraction of recurrent neural network (RNN). In addition to the output of the $(n-1)$ layer of neurons at time t, it also includes its own output at time $(m-1)$. This article also incorporates the student emotion recognition model in the algorithm, as shown in Figure 1.

As shown in Figure 2, X_{t-1} is input of the input layer at time $t-1$, and the hidden layer has an initialization state, that is, the initial value h_0. The h_{t-1} unit in the hidden layer will perform weight calculations, and X_{t-1} and h_0 will perform hyperbolic tangent function calculations using the following equation [15]:

$$\begin{aligned} h_{t-1} &= \tanh\left(W\left[h_0, x_{t-1}\right] + b\right), \\ f(x) &= \tanh(x) = \frac{\sinh(x)}{\cosh(x)} = \frac{e^x - e^{-x}}{e^x + e^{-x}}. \end{aligned} \tag{1}$$

If the hidden layer's weight parameter is different from the input layer's weight parameter, then

$$h_t = f\left(\left[U\left(h_{t-1}\right) + W\left(x_t\right)\right]\right). \tag{2}$$

Through calculation, the hidden layer state h_{t-1} is generated, and the result O_{t-1} is output at the same time. Among them, h_{t-1} cannot be output directly and needs to be normalized using the softmax function. Before softmax processing, h_{t-1} needs to be multiplied by a weight matrix V, using the following equation[16]:

$$\begin{aligned} h_t &= \tanh\left(W\left[h_{t-1}, y_t, C\right] + b\right), \\ O_{t-1} &= \operatorname{soft\,max}\left(V h_{t-1} + c\right). \end{aligned} \tag{3}$$

In the same way, the hidden layer state h_{t-1} generated at time $t-1$ and the input X_t at time t are used as the input of the h_t neuron and the hyperbolic tangent operation is performed to generate the hidden layer h_t state. At the same time, softmax is used for normalization to output the result O_t.

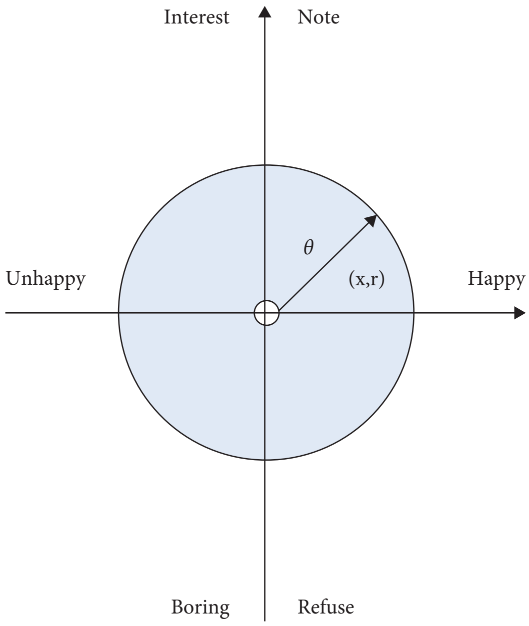

Figure 1: Student emotion model.

When solving the actual text processing problem, most of the input and output sequences are not the same length, so in order to meet the particularity of natural language processing, an *N-M* transform is performed on the basis of the RNN network, that is, the encoder-decoder model. The whole model is divided into two parts: encoder and decoder. The encoder converts a changeable input original text sequence into a fixed-length meaning vector C. The decoder converts the meaning vector C with a fixed length into a target text sequence $S = \{W_1^S, W_2^S, \ldots, W_n^S\}$ with a variable length [17].

In this paper, RNN is described as the basic network structure of the encoder layer and decoder layer. The main task of the encoder layer is to process the input layer data and compress the input sequence into a vector of specified length. This vector is called the meaning vector C. The decoder layer is mainly used to generate output, generate a specified sequence based on the meaning vector, and use the meaning code C to connect between encoder and decoder. There are two ways to use meaning vectors in the decoder.

(1) The semantic vector C in the coding layer is only used as an initial state to participate in the operation, and all operations after the decoding layer have nothing to do with the semantic vector C. In other words, the meaning vector only works at the beginning.

(2) Another processing method is that the word sense vector C participates in the calculation of the sequence at all times, and different vectors that generate the semantic vector at different times work on the decoder.

As shown in Figure 3, the encoder first performs RNN processing on the input sentence. Moreover, unlike the steps that are not output, the calculation result of each hidden layer neural unit directly serves as the input of the next neuron. After that, through the RNN, the intermediate meaning vector C is obtained [18].

As shown in Figure 3, the encoder first performs RNN processing on the input sentence. The difference is that there is no output in this step, but the calculation result of each hidden layer neural unit is directly used as the input of the next neuron. Then, the intermediate semantic vector C is obtained through the RNN, in which the final state h_4 can be obtained or h_4 can be subjected to functional operations. The function formula is [19]

$$C = \tanh\left(Uh_t\right), \tag{4}$$

where U is the weight matrix and h_t is the last hidden layer state of the encoder layer. The initial value h_0 and the start signal y_0 are operated together with the semantic vector C to generate the hidden layer state h_1 and generate y_1. Then, h_1, y_1, and the semantic vector C are budgeted together to generate the hidden layer state h_2 and output y_2, which are passed on in turn, and the final output result is obtained. The formula is

$$\begin{aligned} h_t &= \tanh\left(W\left[h_{t-1}, y_t, C\right] + b\right), \\ O_t &= \operatorname{soft\,max}\left(Vh_t + c\right). \end{aligned} \tag{5}$$

The meaning of C as a semantic vector is to play a role in every moment of its decoder. It can be expressed as

$$\begin{aligned} h_1 &= \tanh\left(W\left[h_0, y_0, C\right] + b\right), \\ O_1 &= \operatorname{soft\,max}\left(Vh_1 + c\right), \\ h_2 &= \tanh\left(W\left[h_1, y_1, C\right] + b\right), \\ O_2 &= \operatorname{soft\,max}\left(Vh_2 + c\right), \\ h_2 &= \tanh\left(W\left[h_1, y_1, C\right] + b\right), \\ O_t &= \operatorname{soft\,max}\left(Vh_n + c\right). \end{aligned} \tag{6}$$

O_t is the output vector at each time, the vector dimension is the length of the vocabulary, and each value of the vector is the probability corresponding to the term. When the probability of the predicted value end signal is the greatest, the prediction ends. The application of the encoder-decoder principle solves the problem of the input and output of the text sequence of the training model. Encoder processes the input sequence, the intermediate meaning vector C stores sequence information, and decoder processes the output sequence, thus realizing the processing from beginning to end.

In the natural language generation task, the LSTM neural network, which is a variant of the recurrent neural network, is usually used as the basic network of the decoder in the architecture. Long short-term memory (LSTM) is a time loop neural network that solves the gradient dispersion problem of traditional RNN models. Now, the LSTM network model is used for generating operations with text sequences [20]. In this model, the pagoda memory model is incorporated, as shown in Figure 4.

σ represents that the control unit controls input, output, and storage, respectively. The control unit is composed of a sigmoid function and a point power action. The value of the sigmoid function is between 0 and 1, and the transmission of information is determined by the

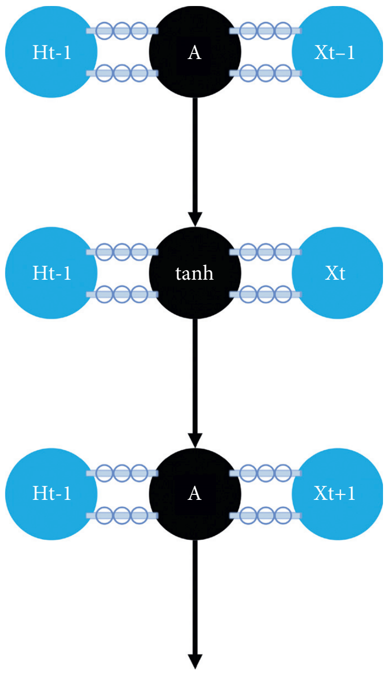

Figure 2: Network computing layer.

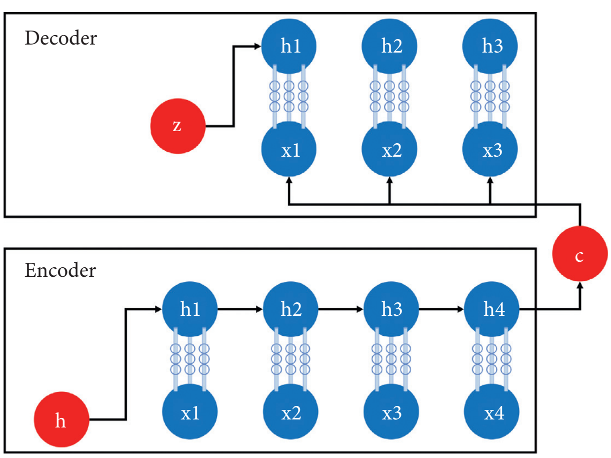

Figure 3: Encoder-decoder structure.

point multiplication operation. At 0, the information is not transmitted, and at 1, the information is all forwarded. The model also joins the cell-state conveyor belt, which is responsible for the storage space of the entire model, and the control unit controls the storage of the storage unit during time conversion. The storage department is responsible for deleting the information required by the three control departments [21].

The input unit stores some current information and combines the past and current storage into the following formula:

$$
\begin{aligned}
i_t &= \sigma\left(W_i \cdot \left[h_{t-1}, x_t\right] + b_i\right),\\
\widetilde{C}_t &= \tanh\left(w_c \cdot \left[h_{t-1}, x_t\right] + b_c\right),\\
\widetilde{C}_t &= f_t * C_{t-1} + i_t * \widetilde{C}_t.
\end{aligned}
\tag{8}
$$

The output unit is responsible for the final output as follows:

$$
\begin{aligned}
O_t &= \sigma\left(W_o \cdot \left[h_{t-1}, x_t\right] + b_o\right),\\
h_t &= O_t * \tanh\left(C_t\right).
\end{aligned}
\tag{9}
$$

By combining the BERT model with the LSTM neural network, text can be automatically generated. In the encoder part, the BERT model can be selected as the encoder in our frame, and the BERT can complete the task of extracting the complex feature information contained in the input text as a bidirectional transformer encoder in multiple layers. This two-way encoding feature solves the word ambiguity problem that is difficult to solve by the traditional model and ensures that the words in each position can pay attention to the information of the adjacent position words. At the same time, the network depth of the 12-layer BERT model can present different characteristic information of each layer through deep analysis of the text.

We use a two-layer LSTM neural network as part of the decoder. In the transformer network structure, the input is mainly composed of word coding and position coding. Position coding is mainly used to record the position information in the input sequence of each term [22].

4. Construction of English Network Teaching System Based on Artificial Intelligence and WBIETS

Aiming at the current situation of English online teaching, this paper analyzes the needs of the teaching system and analyzes the actual situation of the system. The system constructed in this paper needs to have system management function, which is the intelligent system of all network teaching systems. Also, the system needs to have a teaching function, which is also the main function of this system. Finally, the system needs to have the function of students' autonomous learning, so the system role setting in this paper mainly includes system administrators, teachers, and students. The corresponding functional management modules mainly include system management, teaching management, and learning management, corresponding to three roles, respectively. The English network teaching system obtained on this basis is shown in Figure 5.

The system server in this paper stores all the information in the system's self-built database, which is convenient for unified management and modification of information. The data layer, logic layer, and presentation layer in the system constructed in this paper are all

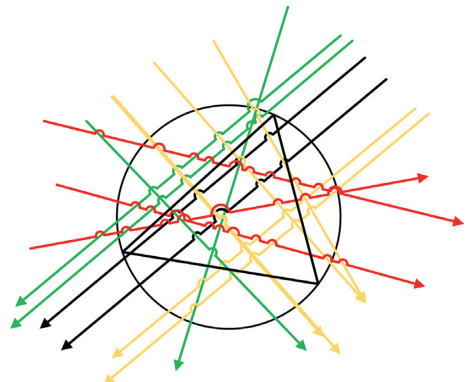

Figure 4: Pagoda memory model.

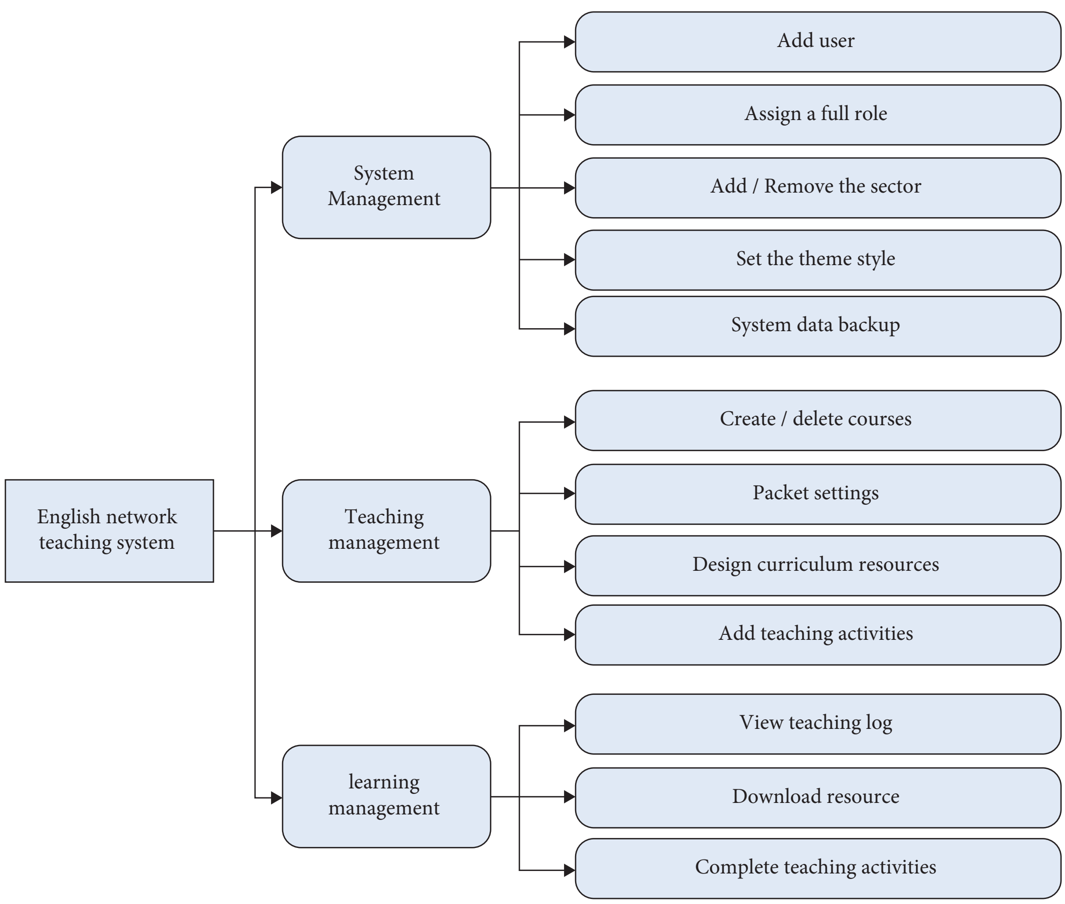

Figure 5: Structure diagram of English network teaching system.

independent of each other, so the system can be effectively expanded when subsequent requirements change. The system constructed in this paper is mainly carried out through the WBIETS system during data processing. The system can provide administrators, teachers, and students with relevant ways to operate the system. Based on the above analysis, the relationship between the elements of the system constructed in this paper can be expressed as the form shown in Figure 6.

From the above analysis, the construction of the English network teaching system is completed. Moreover, the effect of the English teaching system can be verified by system simulation through the simulation system. After that, this paper analyzes the English network teaching system constructed in this paper. The innovation of this system lies in the collection and processing of network data through WBIETS, which enables the teaching system constructed in this paper to be used as English teaching

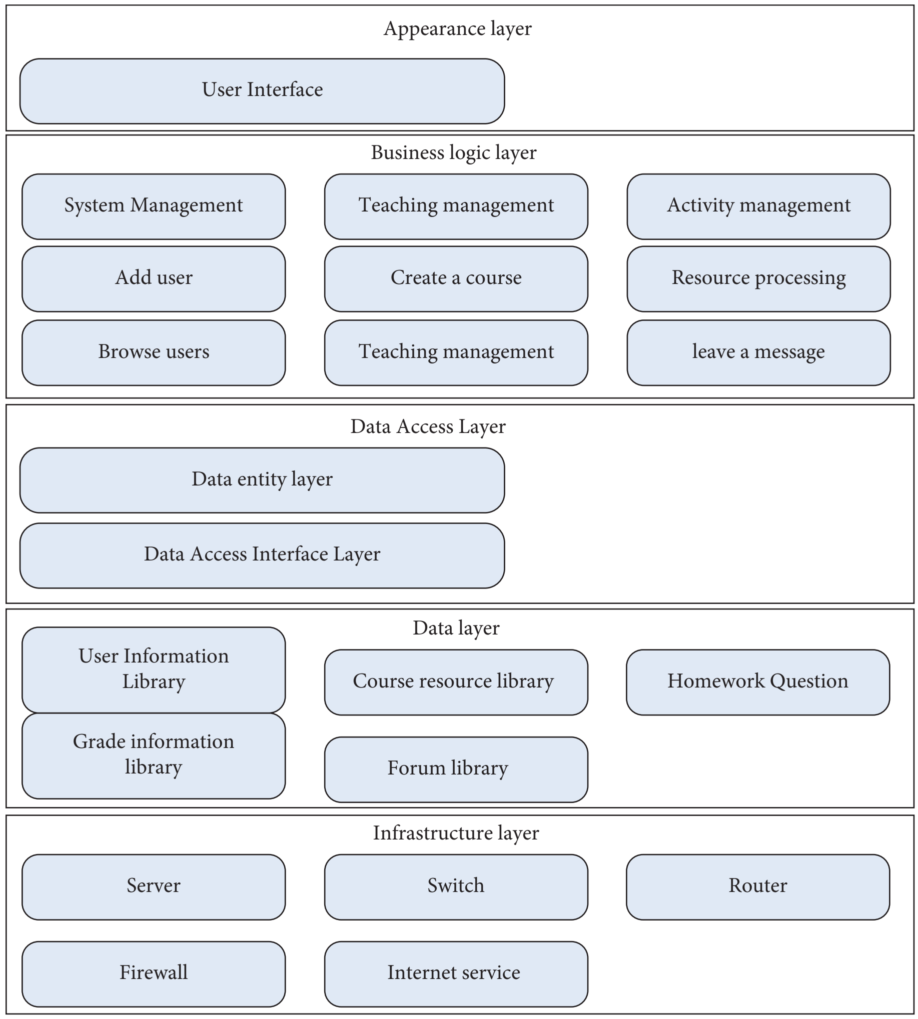

Figure 6: System function structure diagram.

resources. Therefore, in the system evaluation, this paper mainly researches the system data collection and data processing effect and teaching effect. Among them, data collection and data processing can be directly referred to as the acquisition and processing of teaching resources. In the experimental research, this paper first evaluates the acquisition and processing effects of the WBIETS system on teaching resources and obtains the corresponding data through simulation. The statistical data are shown in Table 1 and Figure 7.

Through the statistics of the acquisition and processing effect of WBIETS teaching resources, it can be known that the system constructed in this paper has certain advantages compared with the traditional model in the acquisition of English teaching resources. On this basis, this paper evaluates the teaching effect of the system through the teaching experiment scoring method, and the results obtained are shown in Table 2 and Figure 8.

From the above experimental analysis results, the system constructed in this paper has a good English teaching system, which can play a certain effect in modern English teaching, and subsequent experimental teaching can be carried out through the system constructed in this paper.

Table 1: The effect of acquisition and processing of WBIETS system on teaching resources.

Num	Resource collection	Resource handling	Num	Resource collection	Resource handling
1	91.9	82.8	21	94.3	76.2
2	94.6	87.9	22	93.7	80.4
3	90.7	86.4	23	91.6	83.6
4	94.4	84.3	24	94.7	87.8
5	92.2	78.8	25	91.8	82.7
6	90.5	76.3	26	92.2	85.6
7	92.2	76.4	27	90.6	82.9
8	93.5	79.5	28	90.7	75.4
9	91.4	76.3	29	94.2	87.8
10	92.7	77.0	30	92.4	84.4
11	93.1	87.9	31	93.9	86.0
12	92.0	87.6	32	93.8	83.9
13	90.9	75.5	33	94.4	75.6
14	91.5	78.8	34	92.6	83.2
15	93.6	84.6	35	92.7	76.9
16	92.0	78.8	36	91.9	76.2
17	93.5	80.7	37	92.0	87.7
18	94.9	75.1	38	93.1	75.5
19	93.2	77.7	39	91.2	83.7
20	92.3	80.5	40	91.9	79.3

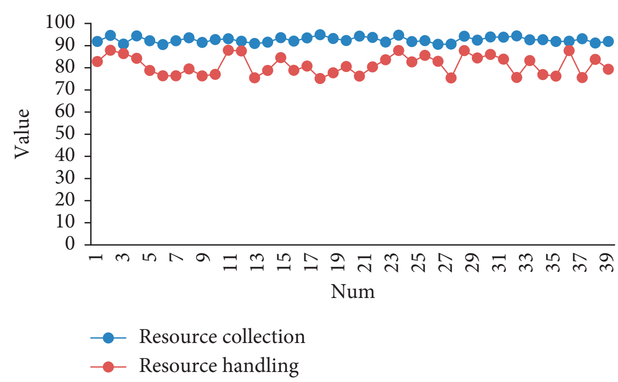

Figure 7: Effect of acquisition and processing of WBIETS system on teaching resources.

Table 2: Evaluation of system teaching effect.

Num	Teaching effect	Num	Teaching effect	Num	Teaching effect	Num	Teaching effect
1	73.5	21	92.0	41	74.2	61	83.8
2	82.8	22	95.4	42	85.8	62	91.7
3	91.8	23	71.6	43	75.2	63	84.9
4	88.1	24	86.2	44	76.3	64	88.1
5	76.7	25	81.0	45	80.9	65	77.0
6	82.1	26	73.8	46	82.5	66	83.2
7	84.9	27	86.6	47	83.1	67	93.6
8	91.0	28	88.0	48	84.7	68	85.6
9	90.9	29	77.2	49	84.2	69	75.1
10	71.7	30	83.0	50	77.3	70	81.2
11	75.5	31	71.7	51	89.6	71	74.2
12	78.8	32	81.7	52	79.0	72	86.5
13	89.2	33	76.6	53	78.8	73	72.6
14	92.5	34	83.7	54	73.2	74	90.6
15	89.9	35	93.5	55	81.3	75	87.1
16	72.4	36	93.3	56	85.0	76	76.4
17	71.9	37	87.2	57	88.8	77	81.4
18	93.6	38	83.8	58	90.0	78	75.6
19	90.7	39	79.5	59	88.6	79	84.1
20	88.1	40	94.4	60	77.9	80	85.4

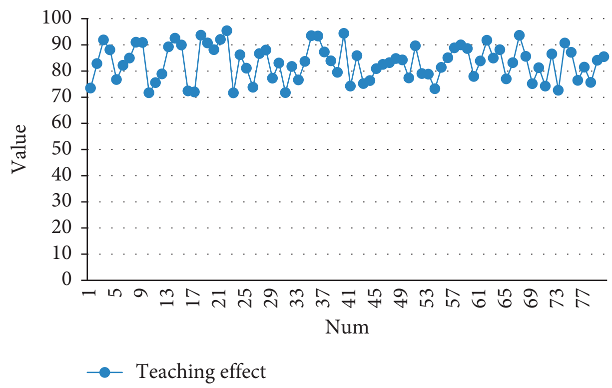

FIGURE 8: Evaluation of system teaching effect.

5. Conclusion

In order to study the system that can be used for English network intelligent teaching, this paper combines artificial intelligence and the WBIETS system to construct an English network teaching system. The data layer, logic layer, and presentation layer in the system constructed in this paper are all independent of each other, so the system can be effectively expanded when subsequent requirements change. Moreover, the data processing of the system constructed in this paper is mainly carried out through the WBIETS system, which can provide administrators, teachers, and students with relevant ways of system operation. In addition, this paper uses an improved algorithm as a base for system design by expanding and constructing it based on the original WBIETS system. In this way, the logical structure and functional modules of the system are obtained to configure the system's response users. Finally, this paper conducts system performance analysis through experimental analysis. From the experimental results, it can be seen that the English network teaching system constructed in this paper can meet the expected teaching needs of an organization.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The author declares that there are no conflicts of interest concerning this work.

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Research Article

Sports and Health Management Using Big Data Based on Voice Feature Processing and Internet of Things

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With the support of big data and information technology, various sectors such as sports, health, and medical industry can realize the integration and readjustment of the existing resources, which improve the operation efficiency of the industry and tap its huge potential. With the advancement in big data analysis, voice features, and Internet of Things (IoT), personalized health management is becoming the development trend and breakthrough of sports and health industry. The application of big data will tap out the huge potential of the sports and health industry. In this paper, we have used the Mel-requency cepstrum coefficient as the speech feature processing method. When the linear frequency is transformed to the Mel frequency by Fourier transform, the calculation accuracy will decrease with the increase in the frequency, and the low-frequency signal will be retained to improve the anti-noise ability. With further study of the voice feature processing and IoT model of big data's sports and health management, a vector addition regression was developed to compare the two real scoring features of the processing results that pave the way for further analysis and result evaluation. Through experimental verification, it is proved that the method in this paper can better learn the speech features. At the same time, with the introduction of noise reduction, the big data of speech recognition in sports health management has a stronger robustness and improves the overall system performance.

1. Introduction

In the education and teaching reforms, there is a lack of scientific and effective information management platform for physical health. In terms of processing and analysis of physical measurement of data, it fails to realize the professional, scientific, and dynamic development of the physical health information management system. Although relevant departments of education are required to collect the physical test data (from primary school to university graduates) every year, there is a lack of systematic and continuous management of the test data, and the efficiency of physical test is relatively low. In view of the fact that the decline of physical health has not been effectively curbed at present, we urgently need to establish a set of individualized and guidance system about physical health management and scientific exercise.

The development of the sports health management system aims at the comprehensive evaluation of physical test results by allowing a comprehensive and accurate understanding of the athlete's health level. Relying on the data in the database to make a detailed classification of physical conditions, the system can provide a more comprehensive system evaluation and more appropriate fitness guidance program for better exercise. After each stage of the test, the system modifies the user's system status according to the difference between the actual physical changes and the expected changes and accordingly modifies the exercise prescription for the next stage. Based on the physical test data and various physical indicators of colleges, a standard database is established [1, 2]. The database not only can help us to check system status but also a detailed classification and effective fitness guidance scheme is given. Since the database is covering a wide range of data, it can help in our effective evaluation system in regional differences and the differences between schools, which can be more targeted to carry out sports activities [3]. Health management can draw lessons from a mental model of society, and at the same time, using the related theories and methods of management, it guides people to improve the life style, form good health habits, and improve the level of people's health. Thus, it helps to improve the quality of life of people, so it is necessary for the government to formulate a series of activities in a planned and organized system. It is not a school or a group that can handle individual behaviors [4, 5]. Health management services must abide by the principle of standardization [6]. Standardization is the foundation of health management. If the cause of health management is to be fully developed, it is impossible to solve some urgent problems such as reducing the incidence of diseases and saving medical costs by relying only on existing conditions. Therefore, it is necessary to draw on effective experience [7]. The development of health management is bound to be benign. Under the guidance and planning of relevant institutions and in the formulation and implementation of government policies and regulations, it is entirely possible for us to establish a strict supervision and management mechanism to create a good atmosphere of health management for everyone [8].

Sports health industry is playing an increasingly important role in the economic development. Sports health industry and other industries have a very strong correlation, in their own development, and at the same time, one can also pull and promote the development of other industries, to provide the all-round development of the economy of power [9]. Of course, the expansion of the sports and health industry will have a greater demand for the number of employees, which will play a positive role in resolving the regional employment problem. This industry itself is the result of the sports industry and health industry's mutual confluence and has a very strong correlation in this new era [10]. The most typical is the sports competitions held allows for the huge promotion that has a significant effect on regional economic development. For example, the Soccer World Cup, an international sports event, needs to improve the infrastructure and increase the construction of venues. At the same time, it also plays a positive role in the local catering and accommodation industry, cultural tourism industry, and lottery industry [11, 12]. Similarly, the health industry, especially the sports and health industry, is closely related to the pharmaceutical industry. Sports rehabilitation and physical fitness measurement are both part of the pharmaceutical industry, and the development of the sports and health industry will naturally promote the development of the pharmaceutical industry [13].

This pattern matching method has been adopted by most speech recognition research institutions. In the 1980s, a major breakthrough was made in acoustic model and speech model. The application of HMM to the acoustic model is an important development stage of speech recognition [14], and the acoustic model based on deep learning as the core has brought a significant improvement in speech recognition rate. In terms of feature extraction, linear predictive analysis [15], perceptual linear prediction coefficient [16], Mel-frequency cepstrum coefficient [17], and FBank feature based on filter banks are carried out frequently [18]. In terms of the language model, recursive big data sports health management, conditional random field, and other new modeling languages are used [19]. In the application of deep learning, the excitation function of hidden layer node is modified and applied to music processing. A multilevel conditional random field is applied to language recognition. Big data sports and health management are directly applied to the HMM state output modeling [20], which reduces the error rate compared with the traditional acoustic model. The current popular deep learning is integrated into the recommender system to study how to integrate multivariate data under big data and build a more appropriate user model to improve the performance of the recommender system [20]. The hybrid recommendation algorithm based on feature and close neighbors was studied by the authors. They combined the matrix algorithm and the collaborative filtering recommendation system based on the project ALS recommendation system, which was based on the matrix decomposition algorithm. The two platforms in the SPARK were executed to test the system [21, 22] and improve the scalability of the collaborative filtering recommendation system [23] and accuracy. The improved system filtering algorithm based on singular decomposition and the improved term-based algorithm were studied, which effectively improved the precision and quality of the recommendation system [24]. The personalized recommendation algorithm based on multiple interests of users is studied, which can deal with the personalized recommendation problem under multiple interests of users [25]. The conditional speech feature processing and the hidden factor model of the Internet of Things (IoT) used for personalized recommendation were studied, which can effectively extract features and can improve the recommendation hit rate of 3.11% compared with the general big data sports and health management system filtering [26, 27].

There are a series of problems in the development of sports and health industry, such as the lack of industry management standardization system, the development mode of sports and health industry is too vague, the lack of professional fitness and health guidance personnel, and low efficiency of publicity, respectively. Affected by the traditional employment environment, the field of sports and health service industry lacks professional technical personnel and management personnel. With the deepening of Internet technology into the economic system, the application of voice feature processing, IoT, and big data technology is necessary; otherwise, it will not be conducive to the sustainable development of the sports and health industry. The combination of sports and health industry and the Internet is a new blue ocean for the joint development of traditional entity industry and e-commerce industry at the present stage. By referring to physique and health assessment indicators, the individual indicators (including individual characteristics analysis, individual dynamic analysis, and correlation analysis of various indicators) are analyzed through big data in this paper. The system carries out complex calculation according to the latest test results of individual and their history, realizes intelligent analysis and calculation through the situation simulator, and provides various forms of result analysis reports. At the same time, the system refers to the evaluation standard to develop tailor-made exercise methods. Our system presents these methods to the Internet. On the one hand, the use of the physique and health system can improve sports enthusiasm. It can also provide the most efficient and scientific guidance methods so as to achieve the purpose of improving physical health level.

The rest of this paper is organized as follows. In Section 2, speech feature processing and big data-enabled sports health management using the Internet of things is discussed. This section is our main work that highlights the significance of this paper. In Section 3, the experimental results and analysis are provided. Finally, the paper is concluded in Section 4.

2. Speech Feature Processing and Big Data-Enabled Sports Health Management Using Internet of Things

In this section, first we discuss the sports health framework which is based on big data analysis. Next, we discuss the voice feature processing and Internet of Things (IoT) for sports health research using big data.

2.1. Big Data-Enabled Sports Health Framework. The original intention of the big data physical health research framework is to promote enthusiasm for exercise, improve physical quality, and provide personalized guidance. Therefore, it is necessary to provide functions that can be accessed independently, rather than only those that are provided solely by the teachers. While using the big data sports health management and fitness guidance system, people only need to input their own personal information to get the relevant data of the physical test at any time. Changing the past physical test data is only in the hands of the test teacher or test department, and they do not understand their own test results that lack the longitudinal and horizontal data comparison phenomenon. Artificial intelligence and physique and health management system can be modified according to individual cervix information matching case in the database that will be the most closest to the truth and then try to analyze the individual status. Thus, the most personalized assessment results will be available that give the customized exercise programs. These results can eventually adjust the exercises according to the guidelines. At any stage, one can exercise the assessment result after transferring to the system that analyzes the latest data according to the physical conditions of the current and changed physical phase difference, to modify the next phase of the training plan. Thus, improvement scheme for the exercise can be provided according to the latest plan to exercise so as to promote the improvement of sports health management level with big data. Its frame diagram is shown in Figure 1.

Setting up the scientific and reliable evaluation standard is the key of the big sports health management system. It is the foundation of the whole system that is as realistic as possible the standardized norm and as far as possible detailed analysis of the physical condition of an individual. This will require a large and diverse data for the support, from low level to high level, so as to form a relatively complete system. Big data used by the sports and fitness guidance system for the management of health management method of collecting data is the first step. We can access the data in sports health management to understand the system parameters. Also, the personal information collected from historical data of the cervix form the basis of our data set. The physical measurement information and physical information in the data set are classified, and each kind of physical condition is matched with the required exercise program, so as to obtain a complete training prescription design process and a big data set of scientific guidance programs, which are our evaluation criteria.

Through a systematic process, the different functions of each department are standardized in operation logic, which are mainly reflected in the following steps:

(1) *Collection and Documentation of Health Data.* This is the first step in health management. Only by collecting all personal health information and understanding their health status, we can effectively maintain health. Our approach adds the personal information in a database by collecting the data from the school health management and physical examination sections. Moreover, a fitness test is conducted every semester in the school hospital and mental health center by collecting the medical record that includes mental health counseling questionnaires regarding the physical health data aggregation and health management system. From the perspective of the school, this system is conducive to enhance the interaction of various departments related to health and evaluate physical health in an all-round and multiangle way. From the perspective of *s*, it is necessary to ensure that are familiar with their own health conditions from a more professional and authoritative perspective and pay more attention to their own health.

(2) *Health Status Analysis and Assessment.* Sports activities according to the individual cervix grades for planning to exercise analysis, to the individuals school hospital records and cervix, combining analysis of evaluation of sports exercise and the feasibility of the project, prescribing a movement, from the perspective of medical health further exercise provide the basis and also provide important reference for physical education teachers teaching arrangement. Using the health management model for comprehensive professional analysis, we evaluate the health status based on an evaluation index to establish the corresponding health grade and further improve their roles for better understanding. This is actually the second step of health management to assess the risk of a disease. If the individuals are aware of the health risks, they will voluntarily rectify their unhealthy behaviors. On this basis, schools can make personalized health management plans, which provide an effective channel for communication between health management departments and individuals.

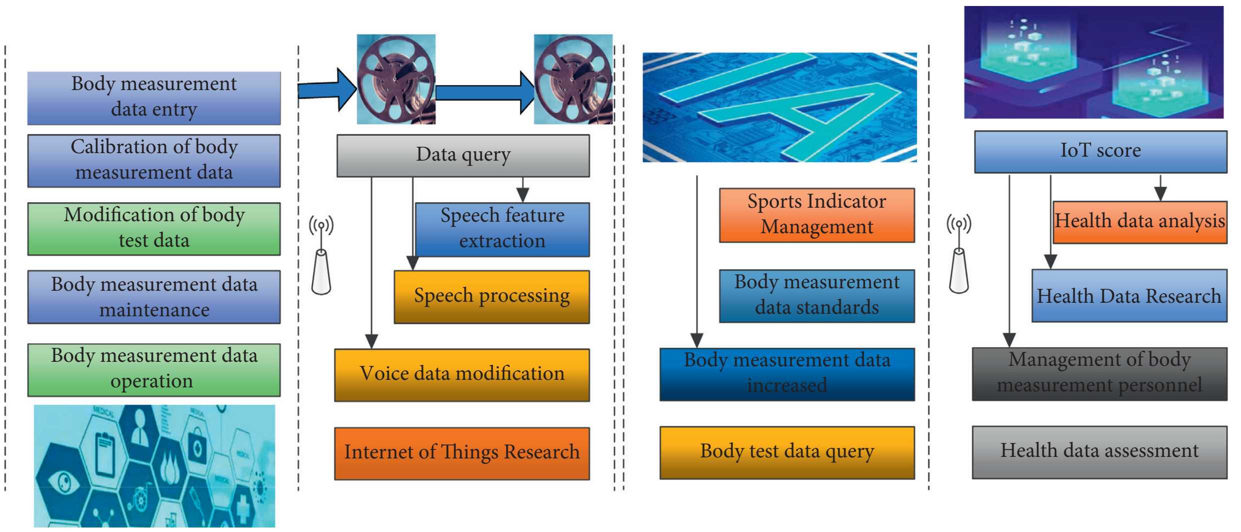

Figure 1: Sports and health framework of big data based on speech feature processing and the IoT.

2.2. Voice Feature Processing and Internet of Things for Sports Health Research with Big Data. After speech signal preprocessing, it is necessary to reduce the influence of irrelevant information and reduce the amount of data for subsequent speech recognition. Therefore, it is necessary to carry out feature extraction for speech signal. The feature extraction method adopted in this paper is the Mel-frequency cepstrum coefficient. The frequency of human speech signal is low, most of the information is contained in the low-frequency part, and the high frequency signal is susceptible to noise interference. MFCC transforms the linear frequency to the Mel-frequency through Fourier transform. Since the calculation accuracy of MFCC will decrease with the increase in frequency, the low-frequency signal will be retained to improve the antinoise ability. The study found that the human ear hears the sound frequency below 1 kHz, the volume increases with the increase in the frequency, and a linear relationship above 1 kHz is a logarithmic relationship. According to this characteristic, MFCC found the correspondence between the actual frequency of speech and Mel frequency:

$$F_{Mrht}(x) = 1150\ \ln\left(\frac{1+x}{800}\right). \tag{1}$$

Extracting the phonetic characteristics of automatic encoder can guarantee good noise robustness, a variation of the automatic encoder structure noise reduction automatic encoder, random erase part of the original input matrix, man-made noise, formation damage data, by fully training speech samples, and susceptibility to particular intelligent household voice control instructions. It greatly increases the accuracy of speech feature extraction. During the training of the autoencoder, in order to make the hidden layer learn more representative characteristics, it is necessary to restore the original data from the noise data so that the autoencoder must conduct noise reduction processing. The extraction flow chart of MFCC voice feature parameters is shown in Figure 2.

The specific steps are as follows:

(a) The speech spectrum FFT is obtained by fast Fourier transform. The preprocessed speech signal of each frame is shown as follows:

$$x_n(t) = \sum_m x_n(m)e^{-u(m)/N^N}. \tag{2}$$

(b) *Calculate the Spectral Line Energy*. The energy of the spectrum is calculated after FFT transformation, as shown in the following:

$$E_n(x) = X_n(t)X_n^T(t). \tag{3}$$

(c) *Calculate the Mel Filter Energy*. Each frame is passed through the filter in turn, and its energy in the Mel filter is calculated. The energy spectrum $E(K)$ of each frame is multiplied by the Mel filter energy, and finally the products are added up.

$$S_n(m) = \sum_{t=0} E_n(x)H_m(x). \tag{4}$$

(d) *Calculate the MFCC Coefficient*. The logarithmic power spectrum is obtained by logarithmic operation of the filter energy, and then the MFCC coefficient is obtained by cosine transformation:

$$C_n(x) = \sum_{m=1}^{M} \log S_n(m)\cos\frac{pt(x-0.5)}{m} \tag{5}$$

Table 1 shows the experimental environment for the development and training of the recommendation algorithm model of sports and health management based on the big data of voice feature processing and the Internet of Things.

The development of the physical health management system aims at the comprehensive evaluation of the results of the physical test so as to have a more comprehensive and accurate understanding of their own health level. By making

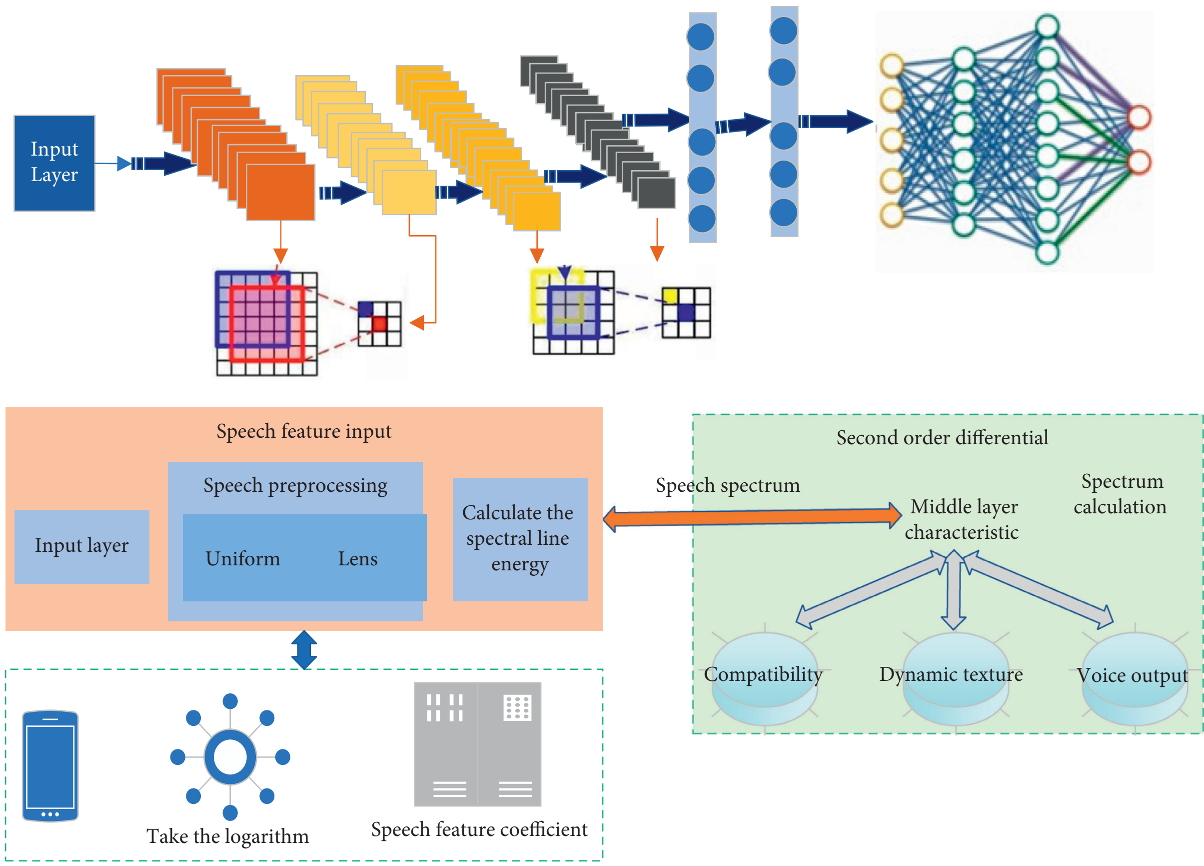

FIGURE 2: MFCC speech feature parameter extraction process.

TABLE 1: Experimental development environment.

Experimental environment	Detailed configuration
Operating system	Windows 10
Processor	i5, 3.0 GHz
A programming language	*Python*3.7
Programming development environment	Jupyter notebook
Deep learning framework	TensorFlow2.0

a detailed classification of the physical condition based on the data in the database, the system can provide a more comprehensive system evaluation and a more appropriate fitness guidance program to guide better exercise. After each stage test, the system will modify the user's system status according to the difference between the actual physical changes and the expected changes and accordingly modify the exercise prescription for the next stage.

A system standard database is established based on the physical test data and various physical indexes of colleges and universities. The database not only helps us to make a detailed classification and effective fitness guidance system but at the same time it covers a wide range of data that allows us to effectively evaluate the system based on regional differences among the schools. In our study, the database is targeted more toward sports activities.

Individual indicators (including individual characteristics analysis, individual dynamic analysis, and correlation analysis of various indicators) were analyzed by referring to physical fitness and health assessment indicators through big data. The system carries out complex calculation according to the latest and historical test results of the individual, realizes intelligent analysis and calculation through the situation simulator, and provides various forms of result analysis reports. At the same time, according to the evaluation standard, a tailored exercise method is developed through calculation. Our system presents these methods over the network. On the one hand, the use of the constitution and health system can improve the enthusiasm of sports; on the other hand, it can also provide the most efficient and scientific guidance methods so as to achieve the purpose of improving the level of physical health. The application of big data in the physical health management system has four advantages: high accuracy, good personalization, timeliness and high efficiency.

By further studying the encoding types of fields in these datasets, it can be found that some fields belong to the same category in the dataset. The usual method of data set processing is to encode these category fields into one hot encoding, but category fields like UserID and FoodID will be transformed into very sparse matrix. There is a phenomenon that the encoding dimension of the input field expands rapidly. This situation should be avoided. Therefore, the algorithm model is shown in Figure 3 in this paper. A vector addition regression was made by comparing the results with

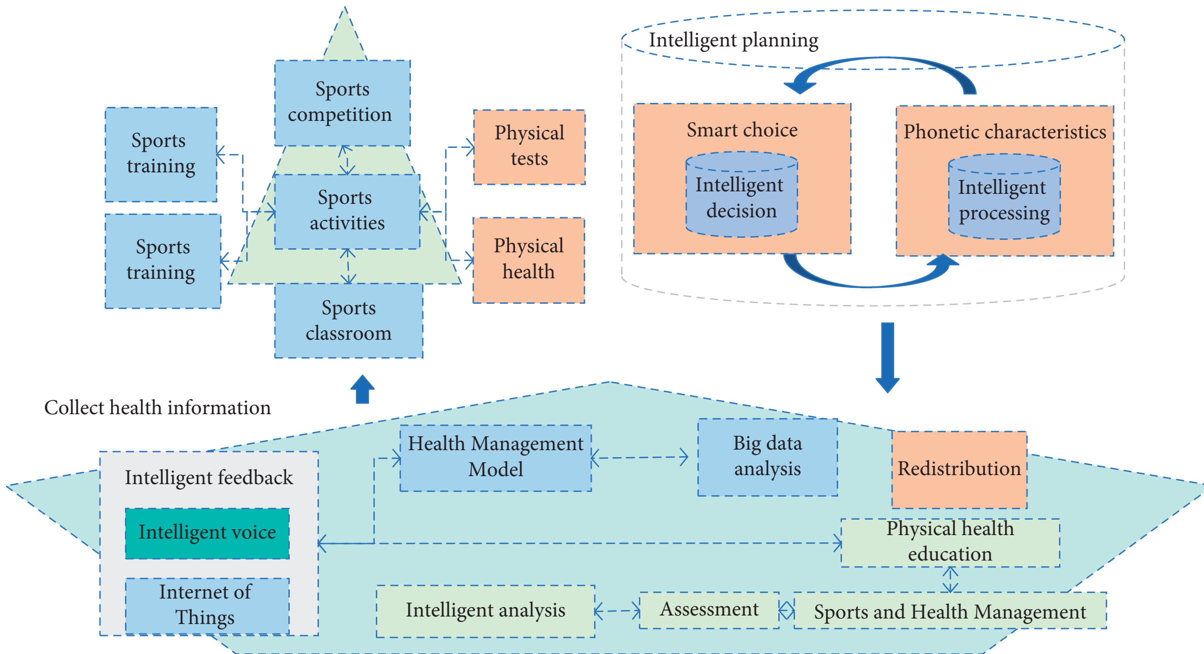

Figure 3: Big data sports and health management algorithm.

the real results of the two scoring features, and the scoring loss was optimized by the MSE method.

Based on the age group, the data of each stage and the ratio of male and female were obtained, and the number and proportion of this age group were quickly found out by the way of age input. The personnel data of each stage are shown in Table 2.

The original intention of the research on sports and health management with big data is to promote enthusiasm for exercise, improve physical quality, and provide personalized guidance. Therefore, it is necessary to provide with rights and functions that can be accessed independently, instead of only teachers having access. When using the big data sports health management and fitness guidance system, they only need to input their own personal information to get the relevant data of the physical test at any time. Changing the past physical test data is only in the hands of the test teacher or test department, and they do not understand their own test results that lack the longitudinal and horizontal data comparison phenomenon. The artificial intelligence and physique and health management system can be modified according to individual cervix information matching case in the database that will be the most close to the truth and then try to analyze the individual status and thus the most personalized assessment results will be available that gives the corresponding exercise program and can eventually take exercise according to the guidelines. At each stage, we can evaluate the assessment results after transfer to the system by analyzing the latest data. According to the physical condition of the existing phase difference, we can modify the next phase of the training plan to provide an improved scheme for exercise, which is in accordance with the latest plan to promote the improvement of sports health management level using big data. Through this system, teachers can count overall sports and health management level with big data and put forward their own sports concepts in the system to understand the significance and suggestions of sports. In addition, teachers can also publish offline tasks in the system to urge to do physical exercises.

Table 2: Personnel data of each stage.

Age	Person
1995	105
1996	194
1997	104
1998	135
1999	124
2000	146

3. Example Verification and Experimental Results

In this paper, the usual performance, the duration of motor skill intervention learning, and the duration of exercise were taken as input indexes, and the changes in assessment performance, psychological cognition, health knowledge cognition, and various physical measurement results were taken as output indexes. According to the established input-output index system, the data are further processed as follows. Data processing of changes in the cognitive level of health knowledge is as follows: according to the scores of health cognition level measured before and after the experiment, the degree of changes in the cognitive level of health knowledge after a semester of study can be obtained. The logarithmic function is used to process changes in the cognitive level of health knowledge. Data processing of changes in psychological cognitive level is as follows: the innovation of this paper lies in the evaluation of mental health cognitive level. Lower the score of psychological state and psychological cognitive level, lower will be the score. The inverse function is used to evaluate changes in the overall psychological cognitive level. As an example, Table 3 provides the sample of data processing.

Comparative experiments in this paper aim to build the phonetic characteristics of 6 implicit layer processing and large data of IoT-enabled sports health management. The extraction of speech signal feature is converted to a 96-dimensional vector with the help of normalized processing and hidden layer activation function using Sigmoid function. The bBatch gradient descent method is used to cumulate values, with the initial vector of 0.03. Because of big data sports health management, increasing the number of nodes is simple than increasing hidden layer units and can effectively improve the recognition. Hence, in this paper, the phonetic characteristics of processing large data of Internet of Things sport health management are studied by adding varying number of hidden layer nodes. In this work, we conducted the study with contrast experiment on the number of hidden layer nodes. The experiment was conducted for different values of *n* such as 10, 20, 30, 40, 50, and 100, with different iterations; loss value is calculated after each iteration is completed, and recognition accuracy is calculated every 10 iterations. Speech feature processing and large data of Internet of things sports health management under different hidden layer node number change curve, and the identification accuracy loss value curve is as shown in Figures 4 and 5; these figures show that with an increase in the number of nodes, the training time and speech recognition accuracy increase. However, after node number 30, the training time increases with the increase in the number of nodes rapidly. Therefore, in deep voice feature processing and big data sports and health management of the Internet of Things, the network performance is the best when the number of hidden layer nodes is 30.

Initialize network parameters according to denoising the autoencoder model. Some network node values were randomly set to 0 to simulate the noise. The initial values of RBM model parameters were obtained by using the random function 0.0006 rand () to get a small value. The bias was set to 0, the learning rate was set to 0.003, and the learning rate of the link weight between hidden layers was set to 0.006. After the training of each layer of the network model is completed, the Softmax activation function is used to fine-tune the network. The maximum number of iterations is set to be 100, and the iteration is stopped when the change rate of the mean square error of the results of two adjacent iterations is less than 0.002. As shown in Figures 6 and 7, the change curve of loss value of three different autoencoders and the recognition accuracy curve show that the 5-layer depth autoencoder has a better recognition rate than the 3-layer autoencoder, while the performance of the deep noise reduction autoencoder is improved compared with the autoencoder. The multilayer encoder network, because of its internal nonlinear structure, can better feature learning, and at the same time, the introduction of noise reduction and the

Table 3: Data processing sample.

Project	Start	End	Change
Pull-ups	1.2	3.6	2.35
1000 m	4045	4035	9.2
100 m	9.6	8.6	0.7123
The sitting body is bent forward	3.5	7.2	4.1372
Mental scale	95	75	19.03
Cognitive level	7	16	9.08

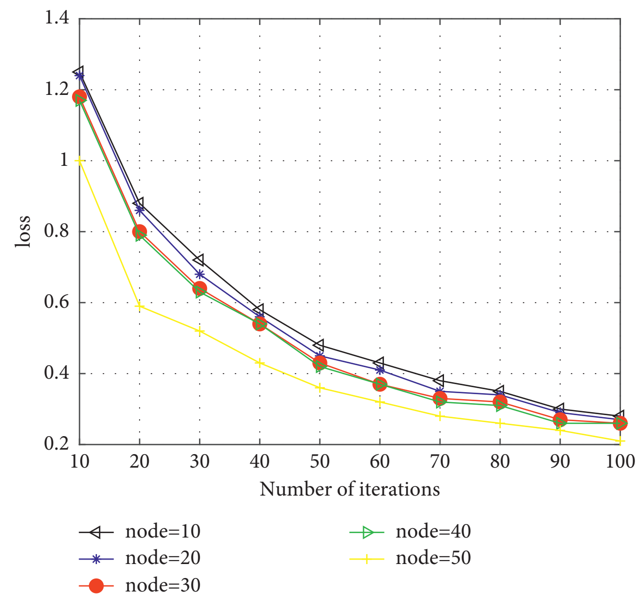

Figure 4: Changing curve of loss value under different nodes of hidden layers.

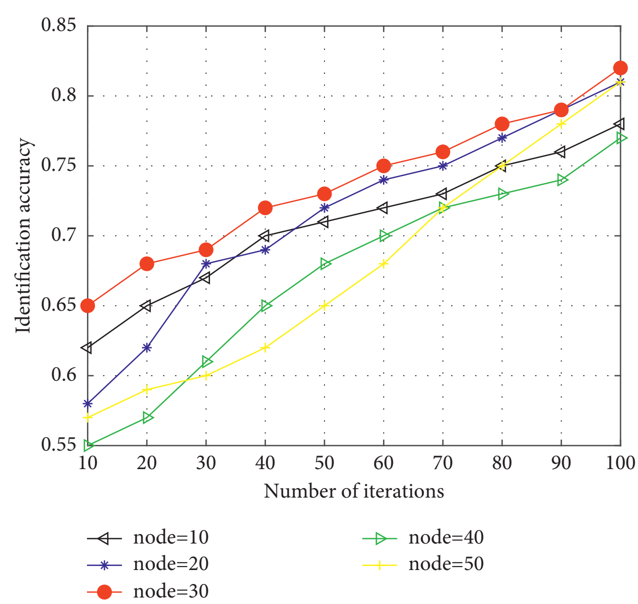

Figure 5: Recognition accuracy curve with different numbers of hidden layer nodes.

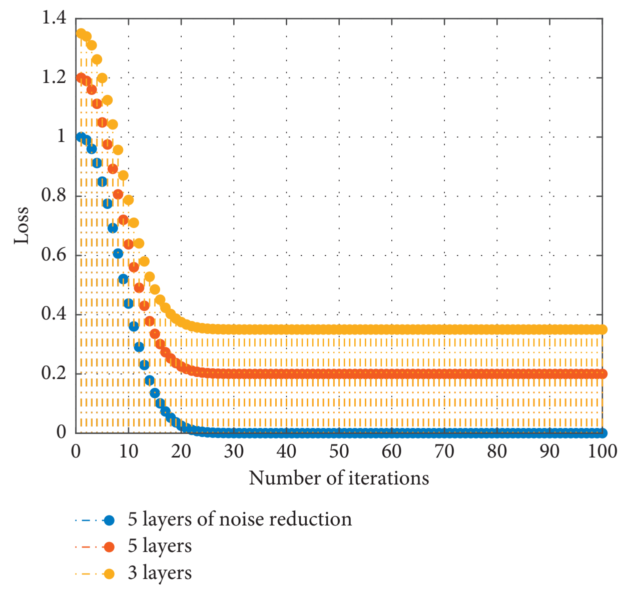

FIGURE 6: Changing curve for loss value of three autoencoders.

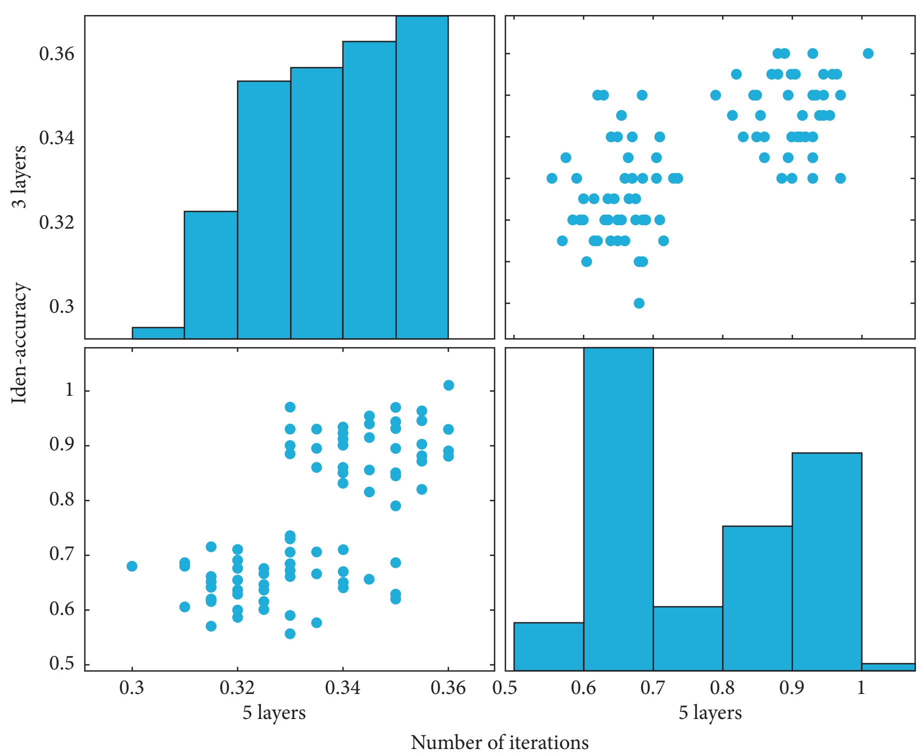

FIGURE 7: Identification accuracy curve for the three autoencoders.

speech recognition results have a stronger robustness and then improve the overall system performance.

Under the same training samples and voice processing and large data of Internet of things compared with sports health management, the noise is increased artificially. The automatic encoder first trains each layer using the voice input characteristics and phonetic features from the low-dimensional ascension to high-dimensional compression. Based on the voice core characteristics, the impact is reduced for each sample. The speech recognition rate is improved by finetuning between layers using supervised training.

The systematic data analysis is mainly based on the systematic processing of the data results obtained from the various physical tests. After the query, it is presented in a visual form. People can intuitively and accurately see the physical and health status of by viewing the visual graphics. Figure 8 shows the visualization effect of the system

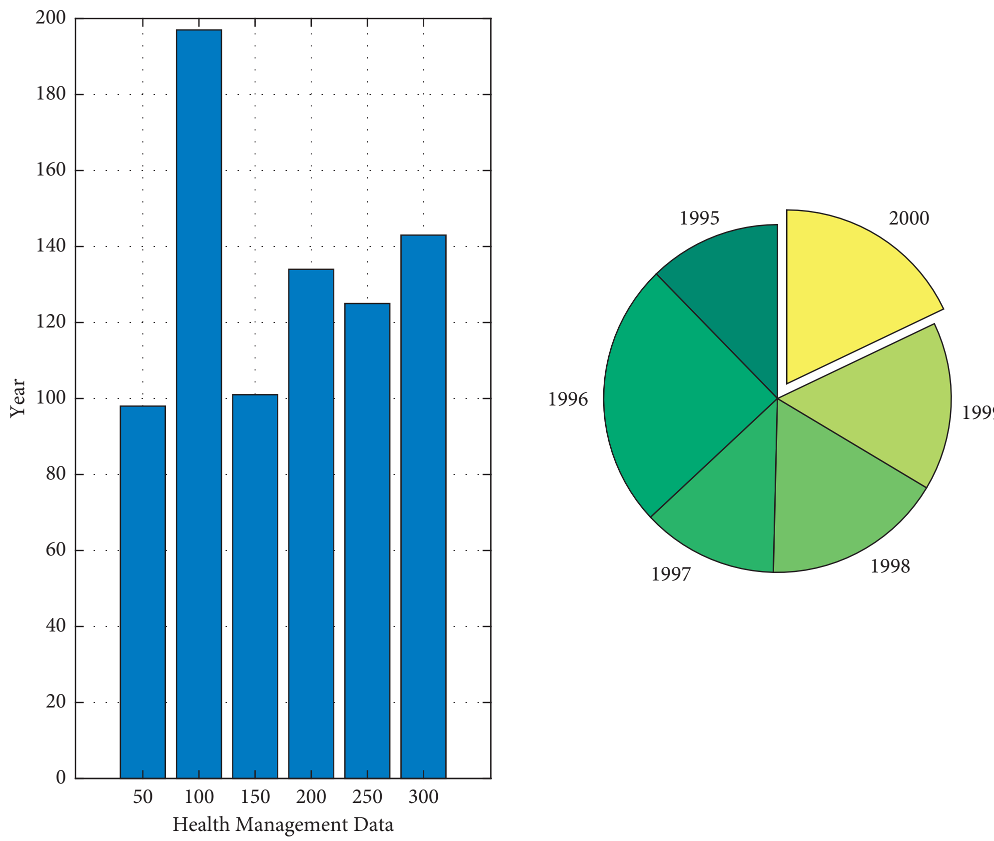

Figure 8: Visualization effects of big data sports and health management of voice feature processing and Internet of Things.

function, voice feature processing, and big data of sports and health management implemented by Redis technology.

4. Conclusion

Physical education departments should stay up with the times, conduct research into body composition and health management using voice feature processing and Internet of Things (IoT) technologies, and implement personalized management and service. The use of big data in a physique and health management system allows for high accuracy, personalization, timeliness, and efficiency in data processing and results in presentation. The sports programme should be tailored to improve the excitement and scientificity of participation in sports and exercise and ultimately to meet the goal of improving health level. The most notable feature of artificial intelligence in physique and health management is that physical quality can be tracked and evaluated in stages at one-stage intervals, and then improved fitness programmes can be provided, promoting the most efficient improvement of physique and health level and achieving the goal of physical education and teaching in schools. In future, we aim to have fog computing integrated with our scheme to improve the efficiency and accuracy even further.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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Research Article

Research on Human Resource Recommendation Algorithm Based on Machine Learning

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The economic environment has changed dramatically around the world in recent years, generating favorable conditions for the growth of small- and medium-sized firms. The socioeconomic development and international integration of China are greatly influenced by the growth in both quality and quantity, the scale of operations, and the internal force of small- and medium-sized businesses. Moreover, in comparison with other developed countries around the world, Chinese small- and medium-sized enterprises continue to face many limitations in terms of size and contribution levels and have not yet fully realized their potentials due to difficulties and poor quality; human resources in this field are still lacking. This study defines the current state of human resources in small and medium firms, the factors that impede development, and the steps that can be taken to overcome these obstacles in order to assist human resource development in this sector during the current period. This study uses machine learning (ML) techniques to manage and analyze human resource data in modern enterprises. The ML techniques realize the functions of the human resource system and reduce the business volume in human resource in order to improve the efficiency and management of the human resource work. In this paper, we designed and implemented the wage forecasting model in human resources that uses a gradient descent algorithm, its types, and backpropagation (BP) neural network to improve the accuracy of the forecasting model. We performed multiple experiments by using a various number of neurons in the hidden layers, different number of iterations, and several types of gradient descent algorithms. The BP neural network model was performed brilliantly by attaining the training accuracy of 89.98% and validation accuracy of 84.05%. The experimental results show the significance and importance of the proposed work.

1. Introduction

Human resource management system (HRMS) is an important tool of enterprise management that plays an important role in the development of enterprises. From its birth to now, HRMS has experienced three stages [1]. The first generation of HRMS appeared in the 1960s. The main objective and functionality of HRMS at that time was to automatically calculate the salaries of employees via a computer system, excluding salary data analysis and nonfinancial information. The main reason for such circumstances at that time was the limited resources and technical requirements. The second generation of HRMS started in the early 1980s. The main drawbacks of the first generation were overcome in the second generation with the development of the database technology and other requirements missing in the first generation. The functions of nonfinancial information, salary data analysis, and report production were kept in consideration, which greatly improved the practicability of HRMS in the enterprises. However, there were still some major problems in the second generation of HRMS; for example, the management process was not standardized and the information processing techniques were not comprehensive. The third generation of HRMS appeared in the late 1990s. Because of the fierce competition among enterprises at that time, especially in the introduction and cultivation of talent, HRM has risen to the top of the company's priority list. Due to the popularity of computers at that time, different technologies, particularly database technology and Internet, had made great progress in the

HRMS. These technologies consolidate human resources for unified management and create integrated data sources, making data analysis and sharing easier.

With the advent of the information age and the development of enterprises, a vast amount of data is produced which needs to be managed and controlled in a well-organized manner. To control, manage, and analyze such a large amount of data is indeed a tough task for human beings to implement at all, so the existence of information management system (MIS) came into being. Management information system (MIS) is management software having the functionality of data collection, database creation, and data management (including data storage and extraction) and can analyze a large amount of data [2–4]. The HRMS is an information management system which combines both HRM and information technology (IT). It is not only an information processing tool but also a resource management standard. Its main purpose is to standardize the business process of the human resource department through the system, concentrate human resource information, and improve the transparency of HRM. HRMS plays an important role in enterprises and has the powerful functions of optimizing business processes, improving work efficiency, and improving management mode. Its quality is directly related to the performance of the enterprise, which affects the survival and development of the enterprise [5, 6]. Therefore, the HRMS is considered an important tool for enterprises. However, in recent years, the data collected by enterprises are growing rapidly and continuously. Such a large amount of data has exceeded the processing capacity of HRMS, which leads to its failure to conduct data management and data analysis normally. This situation is described as "rich data, but the information is poor." Furthermore, the majority of the enterprise-level HRMS has not been fully utilized, with only data collection and storage, no effective data management and analysis, and no use of a large amount of data, wasting not only the enterprise's limited resources but also the opportunity to use big data to develop rapidly. Due to the fact that the traditional HRMS cannot fulfill the needs of organizations' while having big data, in order to make the system work normally, it must artificially screen and process such a vast amount of data, thereby reducing the volume of big data. However, this kind of processing method is back to the old era of manual data processing, which seriously affects the improvement and efficiency of the work. Therefore, people started the use of data mining techniques to reduce the data to be processed [7, 8]. The purpose of data mining is to analyze and find out the important data patterns in the massive amount of raw data and finally convert the original data into useful information and knowledge.

The 21st century is the era of big data that brought a revolution in every aspect of human life such as healthcare, industries, government sectors, social media, and business organization and changed the policies of human resource management [9, 10]. The traditional HRMS can realize the functionality of data entry, query, and statistics but cannot analyze the relationship between data samples effectively and cannot predict the future development of enterprises according to the existing data. To solve this problem, people put forward using data mining techniques to extract and analyze big data. Machine learning (ML) is one of the main tools to realize data mining, and it has various applications in different fields, including the field of HRM and businesses. The important roles of ML in human resource management include recruitment, talent management, preventing brain drain, and improving human resource precise management and are analyzed in detail by different researchers [11, 12]. In a study conducted by Chen et al. [13], they presented the capability of data mining techniques in the development of the decision-making process of HRMS. The significance of data mining in turnover management is analyzed and implemented by Meng [14]. They presented a knowledge discovery approach to assist firms in predicting the future performance of their employees and then assigning relevant personnel to the appropriate project positions.

In this paper, a fuzzy clustering method based on an adaptive genetic algorithm is proposed that provides effective data analysis for the performance appraisal of employees in human resource management of modern enterprises. The potential of AI in HRM is explored in much detail in different studies, among which six scenarios are turnover prediction of the artificial neural network (ANN), candidate search based on a knowledge search engine, personnel scheduling of genetic algorithm, HR emotion analysis, resume data collection and extraction of information, and interactive voice response employee self-service. Some of the basic contributions of this paper are given as follows:

(1) This study designs and implements the model of human position matching using ML algorithms, which can provide a guarantee for effective human resource allocation.

(2) A new method is proposed to evaluate the candidates in an online recruitment system and to solve the problem of candidate ranking using ML algorithms. Further, a new algorithm based on support vector regression is designed for the prediction of the human resource demand of enterprises which has a good practical reference value.

(3) To solve the problem of staff turnover, an extreme gradient boosting (XGBoost) algorithm is used to predict the employee turnover rate. It is proved with the help of experimental results that it is more accurate than the other supervised classification algorithms in predicting employees' turnover.

(4) Based on the work and life situation, this study analyzes the factors affecting the retirement of employees and uses ML algorithms to create a retirement prediction model, which can provide solutions for the outflow of human resources. Further, this study realizes a human resource ranking model, which can predict the ranking and classification of resumes with high accuracy, and effectively simplifies the work of human resources.

The rest of the paper is organized as follows. Section 2 represents the related work, while Section 3 illustrates the applications of the backpropagation neural network (BPNN) in wage forecast. Section 4 demonstrates the experimental simulations and results analysis, and finally, Section 5 concludes the research work.

2. Related Work

The term "human resources" was initially coined in the early 1970s, when the importance of labor relations became more widely recognized, and concepts like motivation, organizational behavior, and selection assessments began to emerge. In "The Human Resources Glossary," Huong [15] describes human resource management as "the people and staff who administer an organization," as opposed to an organization's financial and material resources. ML is a subject that studies how to improve the performance of the system itself using calculation and experience. In general, it transforms the unordered data into useful information through calculation, and this information generally refers to the model obtained through training and learning. With the use of computer systems for human resource tasks, HRM has experienced significant changes since the 1980s. Initially, human resource professionals used these systems primarily as record-keeping systems for simple operations like accepting and storing job applications on behalf of their employers [16]. However, as information technology (IT) advanced, HR professionals began to employ sophisticated computer systems to do the majority of their everyday tasks and make strategic decisions. As a result, HR procedures have been greatly simplified [17]. IT is increasingly and widely used in HRM, and complex computer systems are required for both internal and external operations such as recruitment, performance assessment, remuneration, outsourcing, compensation, onboarding, development, strategic analytics, and business-to-employees (B2E). The advancement in computer engineering has resulted in the emergence of advanced technologies like artificial intelligence (AI). AI is also bringing up significant changes. HRM, a tech-dependent phenomenon, has recently seen such a shift. These significant shifts in HRM that we are witnessing are well worth investigating. The industrial revolution in the 18th century caused a significant shift in industries and economics [18]. These significant shifts in HRM that we are witnessing are well worth investigating [19]. Manufacturers encountered the scientific management paradigm in the early 20th century, which promoted standard-performance production as the optimum approach to achieve maximum profitability [20]. Employers at the time were more concerned with employee production rather than with employee satisfaction, owing to the application of scientific management techniques and the lack of governmental regulation and law governing personnel policies and practices. The widespread study of human behavior, as well as dramatic changes in the structure and intensity of worldwide competition between large organizations, had a significant impact on personnel management methods near the end of the 20th century, and as a result, HRM emerged [21].

HRM has become the standard technique for managing people inside a business since the early 1980s [22]. It has been highlighted as an important method for developing management systems that effectively steer human competencies toward corporate goals since then [23]. With the rise of the Internet as a professional platform and technological advancements, human resource information is evolved into a central hub for human resource management. Electronic HR is the more generic term for the use of computer technology in HR [24]. E-HRM appears to have become the prevalent word for referring to virtual HR or e-enabled HRM in the last two decades, in which IT is used to implement comprehensive HR functions within a business [25, 26]. In general, it is regarded to be useful since it is designed to improve HR efficiency, save costs, minimize administrative responsibilities, simplify HR planning, and empower HR practitioners to become strategic or business partners in firms. According to Marler and Parry [27], e-HRM may not be as cost-effective as it claims to be. Organizations have been transitioning from traditional face-to-face HR procedures to current electronic ones; e-HRM is becoming an important theoretical and practical phenomenon [28, 29]. Many individuals expected e-HRM to revolutionize the way HRM is done in organizations, moving it away from being purely administrative and toward being more strategic. According to Thite et al. [30], the electronic transition faces two major hurdles in the perspectives of business and technology leaders. One is HR's ability to assist business leaders in adopting a digital mindset, as well as a digital way of managing, organizing, and leading change. The second is HR's ability to transform the whole experience of employee by transforming HR processes, systems, and the HR organization via novel digital platforms, applications, and way to deliver HR services.

Information technology (IT) is on many people's agendas, especially professionals and academics, as a crucial commercial tool for many firms. What is more intriguing is that there's a global effort underway to improve IT's qualities using AI, often known as cognitive computing. According to Pan [31], since 2010, several IT behemoths have bought approximately 140 AI start-ups. These businessmen are attempting to combine artificial intelligence (AI) into a variety of computer systems in order to produce seamless experiences during the installation of these technologies. AI strives to make machines capable of performing tasks in the same way that humans do. However, given the fact that people have not yet completely deciphered and grasped the human intelligence that AI simulates, Shah and Warwick [32] believe that computers functioning like human beings should be viewed in terms of imitation. The Japanese Cabinet has announced a new project called Society 5.0 with the goal of bringing about societal improvement. This new approach appears to be aimed at achieving a high level of human-machine interaction [33]. Its goal is to connect people, objects, and computers in cyberspace, using sensors to detect commands and AI to execute them [34]. Unlike the idea of Business 4.0, which we are approaching, Society 5.0 is not limited to the industrial industry but rather penetrates social life as AI, the Internet of Things (IoT), augmented reality, and robotics come together [35].

In this paper, a new HR recommendation algorithm based on the hidden semantic model and the deep forest is proposed in document, which can better recommend the interesting posts for the users. Various studies made an attempt to understand that whether machine learning (ML) can be effectively used to perform potential assessments using preventive methods, thus helping or even replacing human resource managers. The ML methods are used in the earlier studies to provide human resource decision support. In this paper, a model of employee turnover based on a gradient descent algorithm and BP neural network is established in document, which can predict the turnover of employees in enterprises and provide enterprises with the opportunity to solve any problems and improve the retention rate. To solve the problem of human resource replacement in technical posts, this study uses supervised ML techniques to predict the appropriate human resources to fill the vacancy of the technical posts. All of these indicate that the influence of ML in the field of human resource management is expanding and has a great potential to improve the efficiency and performance of HRMS.

3. Applications of ML and Backpropagation Neural Network (BPNN) in Wage Forecast

According to R. Michalski, research in the field of ML can be divided into "learning from examples," "learning in problem-solving and planning," "learning through observation and discovery," and "learning from instructions." According to E. A. Feigenbaum, in the manual of AI, ML can be divided into "mechanical learning," "teaching-learning," "analogy learning," and "inductive learning." At present, inductive learning is the most widely used learning technique of ML. There are three main streams of inductive learning: connectionist learning based on neural networks, semiotic learning, and statistician learning. Connectionism learning based on neural networks is learning of the ML model that simulates the functionality of the neurons of the human brain, and its work in terms of ML is represented by the perceptron, although connectionism learning started early and encountered great obstacles. The main reason was that the neural network at that time could only deal with a simple linear problem and even could not solve the small problem of XOR, which led to the development and learning of the neural networks. Semiotic learning was originated from mathematical logic, and its core idea is to predict the results through the deduction and inverse deduction of symbols, which mainly represents decision tree and logic-based learning. Statistical learning is used to apply statistical learning knowledge to ML techniques, and its representative technology is SVM and "kernel method."

Neural network is a parallel interconnected network composed of adaptive simple units, and its organization can simulate the interaction of biological neural system to real-world objects. The "simple unit" in the definition of a neural network refers to the neuron model, and the neuron model generally refers to the "MP neuron model or single-layer perceptron model" proposed by McCulloch and others in 1943 [14]. In the model, firstly, the neurons get input signals from the environment and then multiply them with the corresponding weights put on the edges. The output of a neuron then becomes the input for another neuron and this process continues until it reached the last layer. Therefore, neurons can calculate the total input signal by multiplying itself with the corresponding weights, then compare it with the threshold value of neurons, and process it via the activation function. At last, the output of the neuron is obtained, as shown in Figure 1.

A neural network is a topological structure consists of various neurons connected via a particular hierarchical structure. Neural network models can be classified into two types based on the hierarchical structure of neurons: interconnection network model and hierarchical network model. The neurons in the hierarchical network model are hierarchical and are generally divided into several layers according to their functions, and each layer is connected, such as the input layer, the middle layer, and the output layer. The interconnection network model is that in which any two neurons can be connected and has certain randomness. The hierarchical network has become the most widely used model structure because of its good structure and easy analysis.

As mentioned earlier, the learning process of the neural network is to adjust the parameters' values of neurons, and the backpropagation (BP) algorithm is used to achieve this purpose in order to reach the target. BP algorithm is based on gradient descent strategy, which takes the negative gradient direction of the target as the search direction to adjust the parameters and finally achieves convergence by continuously iterating and updating the parameters. It is one of the most successful neural network algorithms and has been used widely in various applications. In general, the BPNN model refers to the multilayer feed-forward neural network trained by the BP algorithm, as shown in Figure 2.

3.1. Model Selection. Salary prediction is a kind of regression problem. The regression prediction models commonly used in ML include linear regression, polynomial regression, ridge regression, lasso regression, elastic network regression, and neural networks. Linear regression is a regression model composed of linear variables. Therefore, the linear relationship between the independent variables and dependent variable must be satisfied; that is, linear regression is only applicable to solve linearly separable problems. In linear regression problems, there exists a linear relationship between variables; as a result, the calculation complexity is low and the training speed is faster. The disadvantage of linear regression is that it is very sensitive to outliers. If there is any outlier in the data, the accuracy of the model will be affected. Polynomial regression is the extension of linear regression, which refers to the regression model with independent variables, having an index greater than 1 in the regression equation. When the independent index is equal to 1, the polynomial regression equation degenerates and becomes a linear regression equation. As in most of the cases, independent variables and dependent variables are not linear, so the polynomial regression is an automatic choice for it, which can solve nonlinear and complex problems with ease. The disadvantage of the polynomial regression model is that

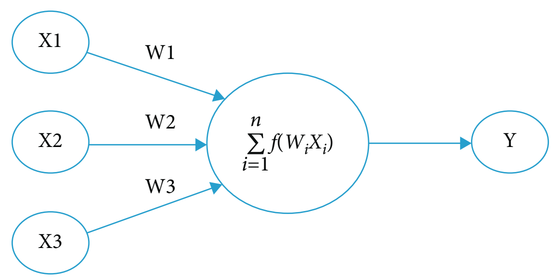

FIGURE 1: Single-layer perceptron model.

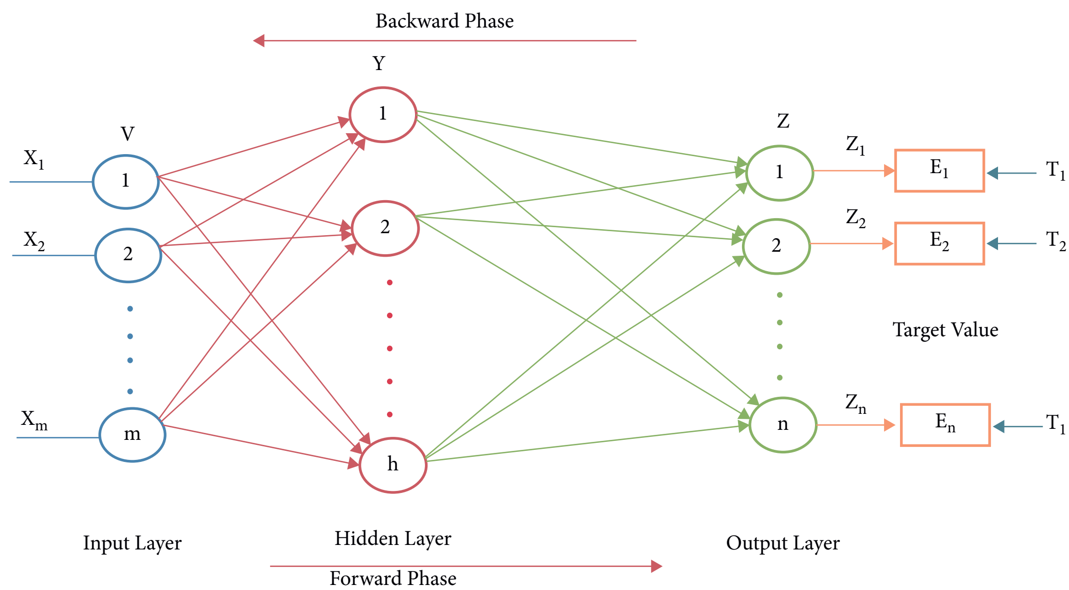

FIGURE 2: General architecture of backpropagation neural network (BPNN) model.

the best index is difficult to determine, the high index is easy to cause overfitting, and the low index is prone to underfitting.

Ridge regression is an optimization technique used when the data features of linear regression or polynomial regression have multiple collinearity (i.e., there is an approximately linear correlation between independent variables). It reduces the influence of multiple collinearities by adding a square bias factor to the regression estimation function (loss function). Lasso regression is similar to ridge regression, and it is also an optimization technique used when the data features of linear regression or polynomial regression have multiple collinearities and also add bias factors to regression estimation function. Only the square offset is added in ridge regression, and the absolute value offset is added in the lasso regression. Elastic net regression is a mixture of ridge regression and lasso regression. It adds both square bias and absolute value offset in regression estimation function, to achieve the common effect of ridge regression and lasso regression. BP neural network is the most widely used type of neural network. Theoretically, a three-layer BP neural network can approach any continuous function with arbitrary precision, has a strong learning ability and simple network structure, and takes low time in calculation. At the same time, neural networks have some shortcomings too. The most important and commonly faced problem in neural networks is the topological structure, parameters initialization, and optimization techniques of neural network. Further, it has a great impact on the training results of the model; if the selection of superparameters is not good, it will significantly affect the performance of the model.

3.2. Salary Forecast Model Based on BP Neural Network. The BP neural network offers nonlinear mapping, generalization, and fault tolerance capabilities. Moreover, the multilayer (three-layer or above) BP neural network can approximate any precision nonlinear function theoretically, which is a powerful ML algorithm. To establish a salary forecast model based on BP neural network, it is necessary to solve the key problems such as topology, activation function selection, and parameter initialization.

The design of the network topology is relatively free and has no fixed form. The hierarchical structure is generally designed according to the nature of the problem. In most cases, the network parameters are also selected according to the nature of the problem and earlier experience. Salary prediction is a mapping of multiple input and a single output. According to the format of data in demand analysis, it can be determined that the number of input layer neurons in the network is 14 and the number of neurons in the output layer is 1. There is no definite calculation method for the number of neurons in the hidden layers. Some methods can be used to estimate its approximate range, and then the model can be trained repeatedly using the trial and error method. Finally, the number of neurons in a hidden layer can be confirmed according to the performance of the model. There are many empirical formulas used to calculate the number of neurons in the hidden layer. The most commonly used formulas to calculate the number of neurons in the hidden layer are given as follows:

$$n_h = \sqrt{n_i \cdot n_o}, \tag{1}$$

$$n_h = \sqrt{n_i \cdot n_o} + k, \tag{2}$$

where n_i is the number of input layer nodes, n_o is the number of output layer nodes, k [1, 10]. According to the empirical formula (2), the range of the number of neurons in the hidden layer is estimated to be [5, 14], then space is slightly expanded to [3, 16] during the training, and the BP neural network is used to train repeatedly.

To sum up, the number of neurons in the input layer, hidden layer, and output layer is 14, 15, and 1, the activation function of neurons is the sigmoid function, the error function (objective function) is a quadratic mean square function, Gaussian random variable with a mean value of 0 and standard deviation of nin is selected as initialization weight, and Gaussian random variable with the mean value of 0 and standard deviation of 1 is selected as initialization threshold.

$$\gamma_j = f'\left(\text{net}_j\right) \sum_k \delta v_{jk} = l_j\left(1 - l_j\right) \sum_k \delta v_{jk}, \tag{3}$$

where yj is the target value of the K nodes and zk is the output value of the K nodes. After the salary forecast model is established, the training can be started. The training flowchart of the model is represented in Figure 3.

In the previous introduction, BP neural network adopts the gradient descent method in the reverse propagation update. According to the amount of data used in each update, the gradient descent method can be divided into three forms: batch gradient descent method, random gradient descent method, and small-batch gradient descent method. Each update is called batch gradient descent which uses all samples to update. Because batch gradient descent needs to use all training samples at every iteration, when the number of training datasets is large, the time of one iteration update will be longer, the cumulative error of all samples will decrease down to a certain extent, and eventually, the training process will be slow. As a result, the batch gradient descent training process may fall into local optimal but cannot achieve global optimization. The method of updating only a single sample is called stochastic gradient descent (SGD). Because SGD only uses a single sample for each iteration update and causes parameter updates very frequently, the update between different sample data may offset each other, which makes each update not advance toward the overall optimization direction, and it is prone to oscillation phenomenon, but this oscillation also makes it possible to jump out of local optimal position and reach global optimal position. The minibatch gradient descent (MBGD) is a compromise method to solve the problems existing in BGD and SGD. It divides the whole sample dataset into small sample datasets and takes the cumulative error gradient of each small sample dataset as the estimation value of the real gradient of the whole sample. When the sample size is large enough, the local error gradient value is approximately equal to the total sample error gradient value. The small-batch gradient descent method can have both bad and SGD advantages.

4. Experimental Simulations and Result Analysis

This section of the paper represents the experimental results carried out via different experiments and their analysis. All the experiments were performed on a laptop computer system having the following specifications: Intel Core-i5, 7th generation, processor of 2.4 GHz, 16 GB of RAM, and the operating system installed on the system being Microsoft Windows 10). Anaconda Jupyter Notebook is used as an IDE for carrying out the simulations. Python has been used as a language for the implementation and for generating the simulation results. The list of python packages used in this study was Keras, TensorFlow, seaborn, Numpy, Matplotlib, and Sklearn, and so on.

4.1. Results of Salary Forecast Model Based on BP Neural Network. This subsection demonstrates the simulation results carried out via the salary forecast model based on BP neural network. All the simulation results were attained using a different number of neurons and iterations as shown in Tables 1 and 2. Table 1 shows the training and validation accuracies of the salary forecast model based on the BP neural network, using the data size of 1000 samples. The dataset samples were divided into training and testing samples, the size of the training dataset was 700, the size of the testing dataset was 300, the number of neurons in each hidden layer was trained 30 times, and finally, the average value of the 30 times results was calculated. The execution process reached its termination when the number of iterations reaches 250.

From Table 1, it is quite obvious that the training and validation accuracies increase as the number of neurons in the hidden layer is increased. Figure 4 shows the training and validation accuracies of the salary forecast model based on the BP neural network.

Figure 4 illustrates that the training and validation accuracies increase with the increase in the number of iterations. The highest training accuracy of 89.98 was attained at the 250th iteration. The highest validation accuracy of 84.05 was also conquered at the 250th iteration.

Table 2 shows the training and validation loss of the salary forecast model based on the BP neural network. The training and validation loss of the BP neural network decrease as the number of neurons in the hidden layer is increased.

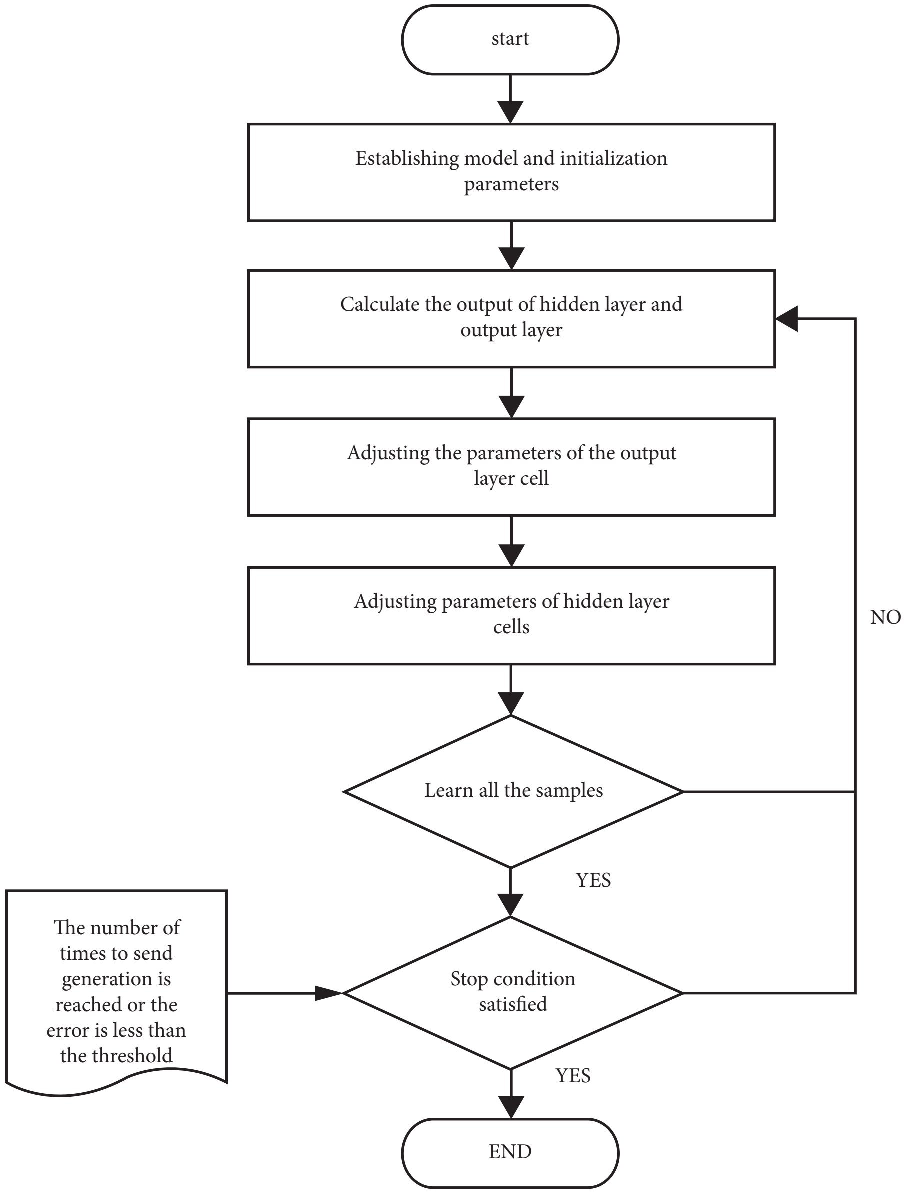

Figure 3: Training flowchart of the wage prediction model.

Table 1: Training and testing accuracies of BP neural network using a different number of neurons in the hidden layer.

Number of neurons	Training accuracy	Validation accuracy
3	86.66	80.04
4	87.04	80.20
5	87.30	80.44
6	87.44	80.52
7	87.46	80.72
8	87.80	80.96
9	87.94	81.22
10	88.00	81.44
11	88.52	81.73
12	88.64	81.93
13	89.00	82.17
14	89.50	83.08
15	89.80	83.86
16	89.98	84.05

We also performed multiple experiments using different gradient descent techniques, that is, batch gradient descent (BGD), stochastic gradient descent (SGD), and minibatch gradient descent (MBGD). To show the training effect of BGD, SGD, and MBGD in an effective way, the loss function curve of these techniques during training is shown in Figure 5. Among them, the horizontal coordinate in Figure 5 is the iteration update times, the ordinate is the loss function (cost), the training sample size is 200, and the small-batch sample size is set to 20. So, BGD performed 200 cycles (read 200 rounds of dataset), MBGD performed 20 cycles, and SGD performed a single cycle.

From Figure 6, it can be seen that when the iteration update time is the same, the convergence results of the three gradient descent methods are relatively close, but the loss change curve is very different: SGD curve has a large fluctuation, BGD curve is relatively smooth, and MBGD is

Table 2: Training and validation loss of BP neural network using a different number of neurons in the hidden layer.

Number of neurons	Training loss	Validation loss
3	0.009975	0.010725
4	0.009958	0.010724
5	0.009950	0.010723
6	0.009954	0.010720
7	0.009947	0.010716
8	0.009944	0.010710
9	0.009940	0.010690
10	0.009938	0.010660
11	0.009932	0.010630
12	0.009928	0.010595
13	0.009926	0.010580
14	0.009920	0.010553
15	0.009916	0.010510
16	0.009912	0.010502

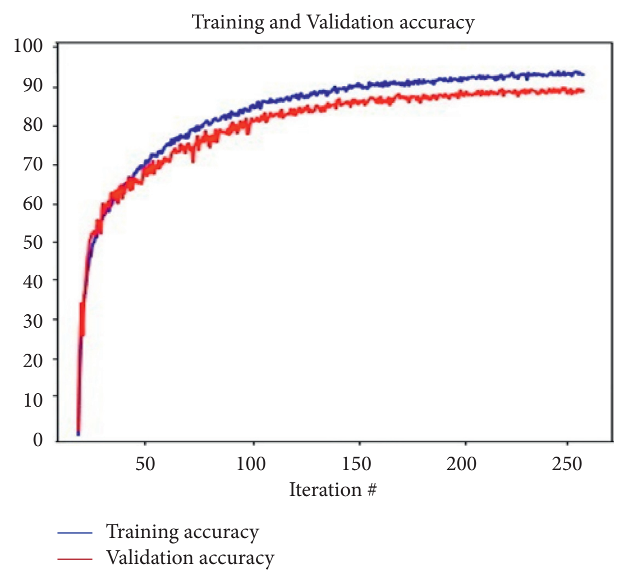

Figure 4: Training and validation accuracies of BP neural network.

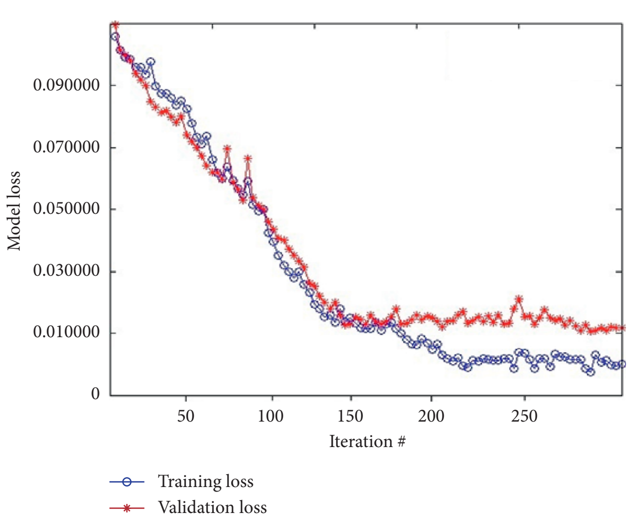

Figure 5: Training and validation loss of BP neural network.

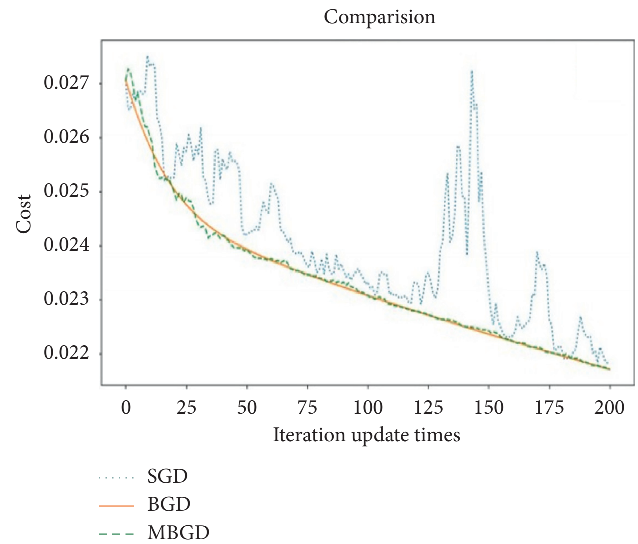

Figure 6: Comparison of SGD, BGD, and MBGD iterative update process.

between SGD and BGD and is relatively stable. The training speed of SGD, BGD, and MBGD is different, and the training period of SGD, BGD, and MBGD is different, which is different from that of SGD, BGD, and MBGD. If the sample space is large, the training speed of the investigated three techniques will be more obvious, especially SGD and BGD. In short, the training speed of SGD is fast and iteration update is frequent, but there is a fluctuation that easily produces oscillation. BGD is stable and iteration update is less, but the training speed is slow. MBGD is a compromise scheme, which has a fast training speed and is relatively stable.

The three-layer BP neural network model used for the salary prediction consists of a different number of neurons in different layers. The number of neurons in the input layer, hidden layer, and output layer is 14, 15, and 1, the activation function is the sigmoid function, the error function is quadratic mean square error (QMSE), and the network parameters are updated by using small-batch gradient descent method (SBGD) and mixed optimization method Nadam. The method used in this experiment divides the dataset into two parts, that is, training and testing. The total sample space selected for the experiment was 1000, of which 900 samples were selected for training while the rest of the 100 samples were selected for testing and validation purpose.

Figure 7 shows the adaptation process and comparison of training effect of various optimization algorithms. In Figure 7, the ordinate is the loss function (cost) and the abscissa is the period (iteration). As can be seen from Figure 7, Adam and Nadam have better performance than other optimization algorithms in terms of convergence speed, whereas Nadam is slightly better than Adam in terms of overall performance.

To better reflect the performance of Nadam based salary prediction model, the comparison results between Nadam and other ML regression algorithms are given here. The size of the training sample space is 900, and the size of the test

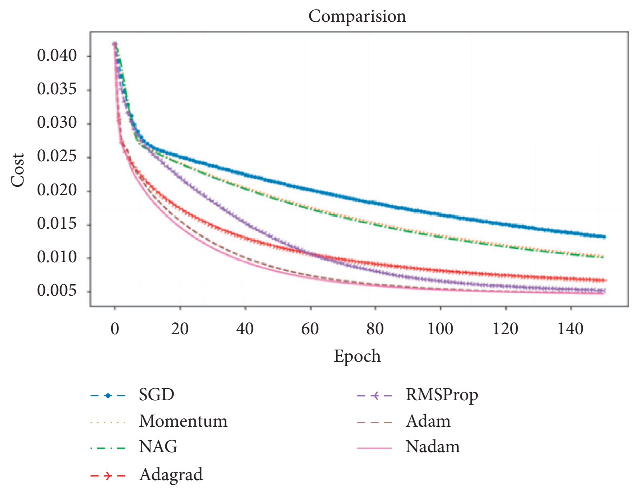

FIGURE 7: Comparison of convergence rates of various optimization methods.

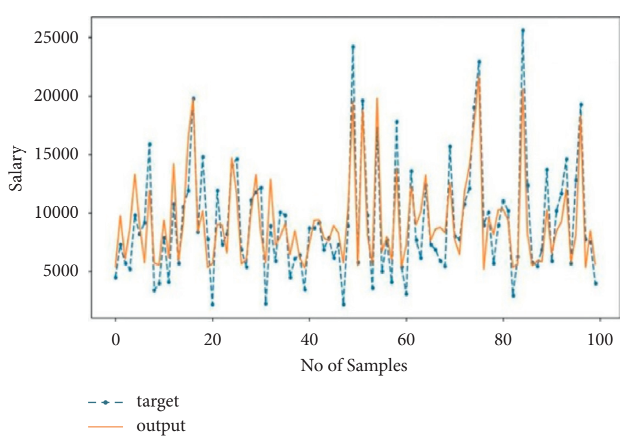

FIGURE 8: Fitting effect of Nadam based salary forecasting model.

sample space is 100. Each algorithm is tested 10 times, and the best test score is obtained. It can be observed that the results of the Nadam optimized salary prediction model in the test set is relatively higher as compared to the other utilized algorithms. Finally, the fitting effect of the Nadam salary prediction model is calculated and is shown in Figure 8.

It can be seen from Figure 8 that the prediction fitting effect of the Nadam based salary prediction model is comparatively higher as compared to the rest of the techniques. Although the normalization and antinormalization of salary data in model training may lead to some errors in calculation, this error is still within the controllable range and has no great influence on the final results of the model. Further, the salary prediction model optimized by Nadam has a fast convergence speed and good prediction effect and has good accuracy as well, so it has certain practical and reference value.

5. Conclusion

Globalization and worldwide economic integration have had a considerable impact on China's economic development, including the business community, in past few years. This results in disparities in many facets of business operations and trade, such as business thinking, observations, confidence, client psychology, behavioral culture, and salary prediction. As a result, for sustainable and adaptive development in the new context, each small- and medium-sized firm must effectively leverage supportive solutions from the government, social media platforms, and small- and medium-sized enterprises themselves. This study mainly focuses on the application and implementation of the BP neural network-based salary forecasting model. Multiple experiments have been performed by using a different number of neurons in the hidden layers and a different number of iterations in order to check the stability and effectiveness of the proposed model. This study also uses the gradient descent algorithm and its types by performing multiple experiments for each of its types. Among the implemented types of gradient descent algorithm, Nadam showed good performance as compared to its other types. BP neural network-based salary forecasting model performed excellently by attaining the training accuracy of 89.98% and validation accuracy of 84.05%. The proposed BP neural network-based salary forecasting model is anticipated to be of great help in human resource management systems.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this study.

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Research Article

Planning the Structure of University Teaching Staff Based on Multiobjective Optimization Method

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University education is a hot topic of research in this era of outcome-based education in a learning-centric atmosphere, as people struggle for a higher quality of life and technological advancements. The key problems remain in structuring the teaching staff to achieve optimal information transmission and quality. Existing research aims to improve the quality of teaching of the staff, but majority of them fail to achieve their objectives. Multiobjective (MO) optimization has attracted researchers' interest, particularly, in the context of performance monitoring and improving teaching quality. The goal of this research is to look into techniques for improving academic accomplishment through the planning structure of university teaching staff. I have adopted the Jaynes maximum entropy principle and fuzzy entropy concept to solve the structural optimization problem in the development of teaching staff in colleges and universities. The objective function and constraints in multiobjective optimization are determined, and the multiobjective optimization issue in the development of teaching staff structure is solved using the nondominated sorting genetic algorithm (NSGA-II) multiobjective genetic algorithm. The results show that the optimized structure of the teaching staff can reflect the goal of the construction of the teaching staff in colleges and universities and provide a scientific basis for the construction and planning of the teaching staff.

1. Introduction

As an important part of the national innovation system, colleges and universities are the main power source to implement the strategy of rejuvenating the country through science and education and the strategy of strengthening the country through talents [1]. The level of college teachers and the degree of their enthusiasm are directly related to the quality of talented graduates and correlated to the development of colleges and universities. With the aggravation of social competition, the social demand for higher education is gradually increasing. How to improve the overall level of university teachers and the quality of personnel training and scientific research level has become a core link in the management of colleges and universities in China. In the process of teaching staff construction, the size of the team, the structure of professional title, the structure of age, and the structure of educational background will affect the level of teaching staff. According to the goal of the construction of university teachers, set by the ministry of education, the structure of university teachers should be more reasonable and standardized, and the overall quality should be greatly improved [2]. Therefore, the construction of teaching staff in colleges and universities should guide the introduction, cultivation, and use of talents through medium- and long-term planning according to reasonable indicators, to achieve the balanced optimization goal of stable scale, strong innovation ability, more teaching, and scientific research output, reasonable salary, harmonious internal relations, and strong sustainable development ability of the whole team [3]. Based on the importance of the above factors, an optimization technique is needed to achieve the goals of university teachers and improve their overall teaching quality.

Optimization is the process of finding the best solution or optimal value from a given problem. The optimization problems include looking for maximum or minimum value or using one objective or multiobjectives. Problems that have more than one objective are referred to as multiobjective optimization (MOO). This type of problem is found in everyday life, such as education, mathematics, engineering, social studies, economics, agriculture, aviation, automotive, and many others [4]. Based on the principles of rationality, high efficiency, and dynamic, this paper proposes a multiobjective optimization method based on fuzzy entropy, which takes advantage of the importance of professional title structure, educational background structure, and age structure in the level of teaching staff and systematically considers the collaborative optimization of each substructure [5]. To solve the multiobjective optimization allocation problem of the planning staff, this research work strives to provide a scientific basis for the planning of the goal of the construction of teaching staff in colleges and universities with the following summarized contributions [6]:

(i) Use multiobjective optimization algorithms to evaluate the system performance.

(ii) Employ maximum entropy to optimize the organization of the teaching personnel. In addition, optimize each objective function using the multiobjective genetic algorithm NS-GA-II (based on nondominated sorting).

(iii) To provide several objective functions and constraints of the teaching staff's construction from the perspectives of professional title structure, educational background structure, and age structure and to solve the multiobjective structural optimization problem in the teaching staff's structure, use the multiobjective genetic algorithm NSGA-II.

(iv) Apply the optimization model to a real-world education system.

(v) Provide efficient system operation for planning the structure of university teaching staff.

The rest of the paper is organized as follows. Section 2 represents the related work. Section 3 highlights the university education system and strategies for optimizing the structure of teaching staff, while Section 4 illustrates the simulation results and experimental analysis. This paper is concluded and research directions for future are provided in Section 5.

2. Related Work

University teaching capacity building, which was traditionally limited to more developed countries, is now becoming a more significant responsibility in both developed and developing countries [7]. In particular, for countries and institutions that are just getting started or striving to improve their research capability and capacity, the university teaching management expertise is critical for growing organizational research capability. Despite this, university teaching administration has been described as "uncharted territory" [5], "mostly untapped territory," and a "modestly recognized" study issue [8]. Teachers are the main allocation resources in the allocation of teachers. The in-depth analysis and mining of teachers' data and the basis of decision-making in education management are the basis of building a teacher allocation model. Through the analysis of teachers' data, it is necessary to accurately evaluate teachers and quantify their teaching ability to improve the quality of education and teaching, which is of great significance to teachers' personal development and students' enjoyment of high quality and good education [1]. The purpose of teacher evaluation is to provide a basis for educational decision-making. The evaluation results should reflect the real situation of teachers and the feedback of students. At present, the evaluation system of teachers in various regions and schools mainly quantifies the evaluation indexes of teachers first and then calculates the average score. The evaluation data come from daily surveys and questionnaires and form several simple numbers to measure teachers' teaching ability. This evaluation method is more reliable, but it does not make full use of these evaluation data. There are also a variety of research methods using a clustering algorithm to establish teacher evaluation or teaching-quality evaluation model. Multiobjective optimization [6] has been used in previous studies to overcome this challenge. Multiobjective optimization [4] is a method for finding the best solution that meets numerous goals. It can emerge as a Pareto solution [9] that consists of a group of complementary options. The researchers in [10–12] have solved multiobjective optimization in building upgrade planning problems by constructing the collection-complementary options and by employing a nondominated sorting genetic algorithm (NSGA-II) among the evolutionary algorithms. The convergence performance of NSGA-II is reduced while addressing the optimization problem with four or more objectives [1]. These research methods regard teachers as multidimensional data objects composed of multiple evaluation indexes, use clustering algorithm to get clustering results, and achieve the purpose of evaluating teachers by analyzing the distribution of evaluation indexes in clustering results. It is very important to select the elements that can accurately describe the characteristics of university teachers, which is of great significance to cultivate high-quality talents and produce high-level research results [3]. At the same time, it is one of the necessary steps to establish the index of evaluating the level of teaching staff. Usually, when evaluating the basic quality of university teachers, we need to consider several important indicators. The goal of this research is to seek optimization techniques to improve the quality of university teaching staff.

3. University Education System and Strategies for Optimizing the Structure of Teaching Staff

This section explains the university education system, including the roles and structures of university faculty [1]. Following that, I go over various ways for optimizing the instructional staff organization. These solutions are broken down into two categories: fuzzy set/fuzzy entropy of teaching staff organization and multiobjective optimization using a genetic algorithm. Finally, I describe a multiobjective optimization method based on a genetic algorithm that I suggested.

3.1. University Education System. Education is a type of learning where a collective's abilities, habits, and information are passed down from generation to generation through training and education [3]. Education is the most significant thing in a person's life since it instills in them the attitudes and knowledge that will allow them to progress professionally and personally throughout their lives.

Improving the general level of university teachers and then improving the quality of personnel training and scientific research is what planning the structure of university teaching staff entails. Before I get into the details of my model, let us take a look at each person's position and structure in university teaching, as well as their academic background, age, and academic relationship [13]:

(i) PhD associated: PhD associated is full-time educational employment with a definite tenure.

(ii) Professor: professorships are full-time positions, but part-time positions are also available. Research (including publication/academic distribution requirements) and research-based teaching are the primary tasks of a professorship. Research-based public-sector consulting could be part of the job description. It could also include sharing knowledge with society, as well as taking part in public debates. Professors may also be in charge of research, course and study program administration, mentoring and supervision, and academic evaluation. In most cases, a professorship is permanent; although, in extraordinary circumstances, it may be temporary. The university determines the specific weighting of the various obligations. The relative importance of various duties may change with time.

(iii) Associate professor: the main tasks of an associate professor are research (including publication/academic communication requirements) and research-based teaching (with related examination duties). In addition to studies and research-based teaching, the role may include knowledge sharing with society, which may include public discussion. Associate professors may also be in charge of research, course and study program management, mentoring and supervision, and academic evaluation. The specific weighting of the various obligations is determined by the university. The relative importance of the various responsibilities may change with time.

(iv) Lecturer: the lecturer role is part-time employment that focuses mostly on teaching. The goal of a lectureship is to allow lecturers with appropriate practical experience or high-level qualifications to work as lecturers. Lecturers must develop and teach courses on their own, following the university's guidelines for lecturing, exams, and other evaluations. Candidates for lectureships are evaluated based on their teaching experience. It is possible to work on a permanent or temporary basis. Within the agreed-upon framework, the particular amount of working hours and any engagement in tests, etc., are set for each semester [14].

Now, I explain different structures such as tile, education, age and academic relationship in university teaching as in Figure 1.

(i) Title structure: it refers to the proportion of professors, associate professors, lecturers, and teaching assistants in the teaching staff of colleges and universities [3]. The structure of professional titles reflects the quality of teachers and the tasks they can undertake. The grade of university teachers' professional titles reflects the academic level of teachers and the level of their teaching and scientific research ability, while the structure of professional titles can reflect the overall academic level and tasks of university teachers. Different types, different foundations, and tasks of colleges and universities have different professional title structures of teaching staff.

(ii) For colleges and universities striving to build research-oriented universities in China, the best structure of teachers' professional titles should be an inverted pyramid structure. This is because, while ensuring the quality of teaching and scientific research, we need to improve the education, teaching ability, and research level of existing teachers to optimize the promotion conditions of existing teachers' professional titles. This increases the number of professors to achieve the inverted pyramid structure standard of teaching staff title in research universities.

(iii) Educational structure: academic structure refers to the proportion of graduates with a doctoral degree, master's degree, and bachelor's degree or below. The educational background and degree of university teachers are important marks of their theoretical level, research level, and potential innovation ability. The academic structure can not only reflect the professional quality of university teachers but also indicate the potential ability of teachers and the development trend of school education and teaching level. The teaching staff of colleges and universities should be mainly composed of doctoral students and master students. Theoretically speaking, the higher the proportion of highly educated teachers in the teaching staff, the higher the quality of education and teaching and the level of research. Therefore, some high-level research universities take the doctor's degree as a necessary condition for teachers.

(iv) Age structure: it refers to the age composition of college teachers [2]. The age structure of teaching staff can reflect the vitality and potential of education, teaching, and scientific research, as well as its comprehensive strength and creativity. A reasonable age structure of teaching staff should be the balanced distribution of the number of teachers in all age groups, and the number of teachers in the best age group (36–50 years old) should be higher than that in other age groups. The age structure of

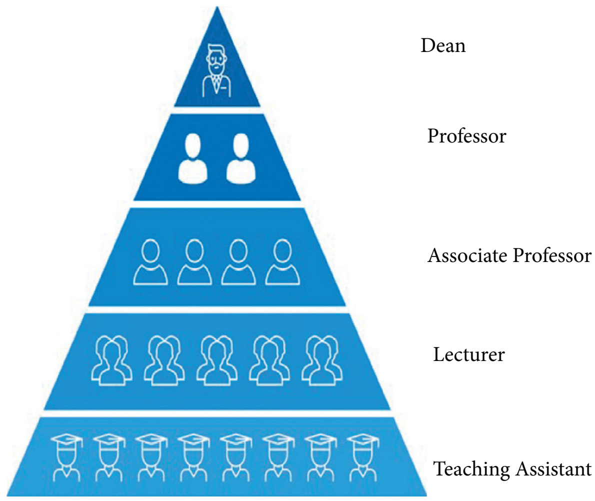

Figure 1: Structure of university teaching staff.

university teachers directly affects the continuity and inheritance of the team. Generally speaking, the teaching staff in colleges and universities should form a reasonable academic echelon of the old, middle age, and young, and the age distribution of the teaching staff should be in a normal curve. According to the relevant data, the proportion of teachers in different age groups is as follows: 25% are under 35 years old, 50% are 36–50 years old, and 25% are over 51 years old. The average age of university teachers should be controlled at about 40 years old, and the average age of professors and associate professors should be controlled at 50 and 45 years old.

(v) Structure of academic relationship: it refers to the structure of the type, level, and distribution of the graduation colleges and majors of a certain degree education among the teachers in colleges and universities [1]. Promoting the optimization of the academic structure of the teaching staff and making the team members come from different regions and different types of colleges and universities, with the interdisciplinary and multitype of the professional knowledge system, will inevitably make colleges and universities have a hundred flowers blooming ideas and characteristics of education and teaching. In the analysis and evaluation of the structure of teaching staff in colleges and universities, the structure of professional title, educational background, and age are the most important factors, and these three substructures restrict each other. The optimization of one structure often means the constraint of other objectives.

According to the above, the focus of this study is on multiobjective optimization of these three substructures, to improve the structure of professional title, academic background, and age. Furthermore, the educational background and age structure should be balanced and optimized.

3.2. Strategies for Optimizing the Structure of Teaching Staff. In today's dynamic and competitive climate, strategic management is critical for educational institutions. It has been employed in a variety of quickly changing circumstances. Both are employed in the sphere of education, particularly, among university lecturers. Furthermore, the strategy implementation process, which focuses on the formation of the university's vision, mission, and teaching staff quality, is an important aspect of strategic management that is often disregarded [15]. For optimization the structure of teaching staff, I have used maximum entropy.

As per [16, 17], the maximum entropy principle (MEP) is a strong reasoning principle that enables one to identify the probabilities that define a system based on the information available, which is typically in the form of averages of random variables of interest. It is founded on the following principles:

(i) The system's enumeration states $i = 1, \ldots, N$

(ii) The addition of one or more functions that convert the system's available information into probability restrictions, such as $f(p) = c$, where c is a vector of average values

(iii) Develop the overall function that measures the uncertainties associated with a probability distribution candidate

Maximum entropy states that if the structure of professional title, the background of education, and the ages of teaching staff are reasonably allocated then the fuzzy entropy corresponding to the structure of these may be reaching to maximum [6]. Therefore, this paper first calculates the fuzzy entropy of title structure, education structure, and age structure and uses them as the objective function of evaluation. After that to realize the balanced optimization of each objective function, the multiobjective genetic algorithm NS-GA-II (based on nondominated sorting) is used to optimize each objective function. The Pareto optimal solution set of fuzzy entropy of each structure is obtained, to determine the balanced optimal allocation of each structure in the teaching staff.

3.2.1. Fuzzy Set and Fuzzy Entropy of the Structure of Teaching Staff. Fuzzy sets are similar to sets with pieces that have varying degrees of membership. As an expansion of the classical notion of set, fuzzy sets were developed separately in 1965 [18, 19]. Entropy, on the contrary, is a measure of a system's dysfunction. Using flavors of entropy to improve algorithms ranging from decision trees to deep neural networks has demonstrated to increase speed and performance because it is much more dynamic than other more inflexible measures such as correctness or even means squared error [19]. To define JAYNES maximum entropy for the proposed system, let us assume that $\theta = \{\theta_1, \theta_2, \ldots, \theta_n\}$ be the parameter space corresponding to the structure state of the teaching staff $(p_1, p_2, \ldots, p_n)$ which is a probability distribution on it; then, the uncertainty degree of the structural state can be used as the probability distribution

$(p_1, p_2, \ldots, p_n)$ expressed by the Shannon entropy defined by

$$\sum_{i}^{n} p_i ln p_i. \quad (1)$$

For the fuzzy set, let U be a universe. A fuzzy set A on U is a mapping from u to the interval [0,1] such that $\mu_A: U \longrightarrow [0,1]$ denotes the value range. For $x \in U$, $\mu_A(x)$ is called the membership of x to A, and $\mu_A(\cdot)$ is called the membership function of a. The fuzzy entropy of fuzzy event A can be defined as

$$H(A) = -\sum_{i=1}^{n} \mu_A(x_i) \cdot p_i ln p_i. \quad (2)$$

In equation (2), $p_i (i = 1, 2, \ldots, n)$ n) is a fuzzy event A, which has some independent probability distribution of possible states and satisfies

$$\sum_{i=1}^{n} p_i = 1. \quad (3)$$

From the above equation, it is cleared that a certain probability distribution P $(i = 1, \cdots, n)$ can be selected to maximize the fuzzy entropy day (a) of fuzzy event A so that the selected probability distribution is the minimum possible estimation based on the given information.

In order to realize the balanced optimization of multiple objectives in the teaching staff, in this research work, I have chosen the fuzzy entropy of title structure, education structure, and age structure as the objective function of multiobjective optimization. Therefore, keeping in view of the above, this paper defines the following three basic domains to plan the desired structure of university teaching staff with the help of the maximum fuzzy entropy method [20, 21].

Domain 1: in this domain, I define the set for title structure of the university teaching staff based on my proposed optimization method. For this purpose, the title set $U_1 = \{$Professor, associate professor, lecturer, teaching assistant$\}$. The number of elements n_1 of title set U_1 is 4, that is, the cardinality of the set $|U_1| = 4$.

Domain 2: in this domain, I have defined a set for education structure of the university teaching staff based on my proposed optimization method. Let us assume that academic degree set $U_2 = \{$doctor, master, undergraduate and below$\}$. The number of elements n_2 of academic degree set U_2 is 3, that is, the cardinality of the set $|U_2| = 3$.

Domain 3: in this domain, I have defined a set for age structure of the university teaching staff based on the proposed optimization method. Let age set $U_3 = \{< 30, 30\text{–}40, 40\text{–}50, >50\}$; the number of elements n_3 of age set U_3 is 4, that is, the cardinality of the set $|U_3| = 4$.

As the different professional titles, educational background and age have different effects on the level of teaching staff [22]. Therefore, I have defined three fuzzy sets below:

(i) In my scheme, the fuzzy set, T, represents the degree set of different professional titles, and its membership degree can be seen in the following equation:

$$\mu_T(x)(x \in U_1). \quad (4)$$

(ii) Besides fuzzy set T, the fuzzy set E represents the degree set of different educational background, and its membership degree can be written as

$$\mu_E(y)(y \in U_2). \quad (5)$$

(iii) Similarly, fuzzy set A represents the degree set of different ages of the proposed university teaching staff, and its membership degree can written as

$$\mu_A(x)(x \in U_3). \quad (6)$$

When the distribution of the structure of professional title, educational background, and age has been determined, then the proportion of teachers with professional title I, educational background J, and age K is given by $P_{ijk} (i = 1, 2, \ldots, n_1; j = 1, 2, \ldots, n_2; k = 1, 2, \ldots, n_3)$.

Here, P_{ijk} satisfies

$$\sum_{i=1}^{n1} \sum_{j=1}^{n2} \sum_{k=1}^{n3} P_{ijk} = 1. \quad (7)$$

In light of equations (4)–(6), the proposed fuzzy entropy of professional title structure, educational background structure, and age structure are presented by equations (8)–(10):

$$H(T) = -\sum_{i=1}^{n1} \mu_T(x_i) \cdot \left[\left(\sum_{j=1}^{n2} \sum_{k=1}^{n3} P_{ijk}\right) \cdot \ln\left(\sum_{j=1}^{n2} \sum_{k=1}^{n3} P_{ijk}\right)\right], (x_i \in U_1), \quad (8)$$

$$\mathrm{H(E)} = -\sum_{i=1}^{n2} \mu_E(y_j) \cdot \left[\left(\sum_{i=1}^{n1} \sum_{k=1}^{n3} P_{ijk}\right) \cdot \ln\left(\sum_{i=1}^{n1} \sum_{k=1}^{n3} P_{ijk}\right)\right], (y_j \in U_2), \quad (9)$$

$$\mathrm{H}(\mathrm{A}) = -\sum_{i=1}^{n3} \mu_A(z_k) \cdot \left[\left(\sum_{i=1}^{n1} \sum_{j=1}^{n2} P_{ijk} \right) \cdot \ln \left(\sum_{i=1}^{n1} \sum_{j=1}^{n2} P_{ijk} \right) \right], (z_k \in U_3). \tag{10}$$

According to the proposed maximum entropy principle [23], if the title structure, education background structure, and age structure in the structure of university faculty reach the optimal and reasonable allocation, then the fuzzy entropy corresponding to each faculty structure reaches the maximum. This means that the multiobjective optimization model can be expressed by

$$(\mathrm{vp})\begin{cases} \max H = [H(T), H(E), H(A)]^A \\ s.t. \sum_{i=1}^{n_1} \sum_{j=1}^{n_2} \sum_{k=1}^{n_3} P_{ijk} = 1, 0 \leq P_{ijk} \leq 1 \\ (i = 1, 2, \ldots, n_1; j = 1, 2, \ldots, n_2; k = 1, 2, \ldots, n_3) \end{cases}. \tag{11}$$

3.2.2. Multiobjective Optimization Based on Genetic Algorithm. In the previous section, I have calculated the fuzzy entropy of title structure, education structure, and age structure and used them as the objective function of evaluation. Now, in this section, I explain the multiobjective genetic algorithm NS-GA-II (based on nondominated sorting) in detail to optimize each objective function.

It is difficult to evaluate the advantages and disadvantages of the solution derived from multiobjective problem objectively [24]. This is because of the mutual restriction (through the decision variables) among the objectives in the multiobjective optimization problems. At the same time, the solution of multiobjective optimization problem is not unique, but there is an optimal solution set, and the elements in the set are Pareto optimal solution or efficient solution. Furthermore, the elements in the Pareto optimal solution set are not comparable to each other for all objectives.

In this paper, I have used the NSGA-II algorithm based on Pareto optimal solution to solve the problem. Besides, the fuzzy entropy of professional title structure, academic degree structure, and age structure in the structure of university teaching staff is taken as the objective function so as to obtain the optimal allocation of professional title structure, academic degree structure, and age structure. The main steps of the proposed NSGA-II algorithm are as follows, and its flow can be seen in Figure 2.

(i) Randomly generated initial population $P_{0,t} = 0$

(ii) The progeny P_0 of population Q_0 was generated, and the population size was N

(iii) Combine parent and offspring population, $R_t = P_t \bigcup Q_t$

(iv) Generate all nondominated fronts of $R_t F=(F_1,F_2,\cdots)$

(v) The congestion comparison operator p_n is used to sort all nondominated fronts

(vi) Choose n best to deconstruct into new population $P_t + 1$

(vii) A new offspring population $Q_t + 1$ was created by selection, crossover, and mutation

(viii) $t = t+1$

(ix) If the maximum propagation algebra is reached, the algorithm is terminated; otherwise, step (iii) is executed

Figure 2 can be explained in following phases:

Phase 1: the initial parameter input is treated within the first phase. System integration parameters and NSGA-II configuration parameters are among these parameters. The majority of system parameters are determined by the type of facility, technical parameters, economic parameters, system operation strategy, and so on. The size of the population (pop), the number of iterations (t), crossover probabilities, and mutation and distribution indices of crossover and mutation procedures are among the NSGA-II parameters.

Phase 2: the second phase is about the initialization of the population which is based on the initialization in phase 1.

Phase 3: this phase is about the operation plan and objective function, which computes the individual fitness function.

Phase 4: phase 4 reserves some of the candidate solutions according to fitness in a fresh population and rejects others.

Phase 5: phase 5 is about crossover and mutation processes. A fresh population is gained by crossover and mutation operation of population. Then, compute the individual fitness function in the population.

Phase 6: phase 6 produces a new population. The new population is attained by considering the rank value and crowding distance.

Phase 7: phase 7 is concerned with the end condition decision. When the maximum evolutionary generation is satisfied, the individual with the maximum fitness gained in the evolution procedure is taken as the optimal solution output, and the calculation is ended.

4. Simulation Results and Experimental Analysis

This section of the paper represents the experiments performed and the simulation results carried out via those experiments. Multiple simulation experiments were conducted to plan the university teaching structure with the help of multiobjective optimization method, i.e., maximum entropy and multiobjective genetic algorithm NS-GA-II (based

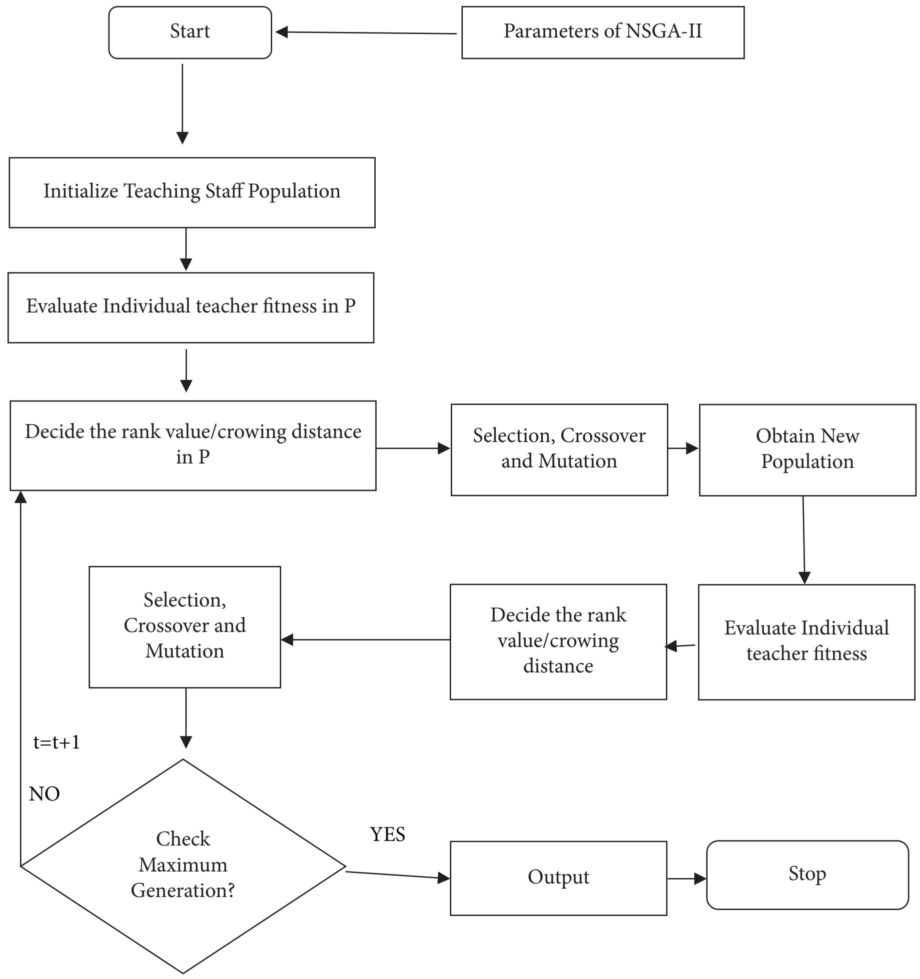

Figure 2: Flow diagram NSGA-II.

on nondominated sorting). I established a university teaching planning structure model for teaching staff for education sectors in real environment. Multiple experiments were performed by using various parameter settings. Among the experiments and simulation results, the top two are discussed here. All the experiments have been performed on a Laptop computer (Dell Core-i5, 7th generation, having a processor of 2.7 GHz, RAM of 32 GB, and the operating system on which it operated was Windows 7).

4.1. Calculation Process. In the process of calculation, for the problem of membership value in maximum entropy, the membership value is obtained by questionnaire survey and fuzzy statistical method [25]. The parameters of NSGA-II algorithm are determined according to the following principles:

(i) A real parameter vector corresponds to a chromosome, and a real number corresponds to a gene

(ii) The initial value assigned to each variable is located in [0, 1] interval and the initial value of each variable is generated by random function

(iii) The fitness function is determined according to the fuzzy entropy of professional title, education background, and age

(iv) The genetic operator, the selection operator, the crossover operator, and the polynomial mutation operator are used, respectively

(v) The population size was 1000, the variation probability was 0.2, the crossover probability was 0.9, and the generation was 200

4.2. Result Analysis. In the teacher allocation model, when the search space is large and the number of iterations is limited, the algorithm is easy to fall into local optimum, so mutation operation and local search are added to the algorithm to improve the diversity of the population. As shown in Figure 3, in multiple experiments for a group of data, different thresholds are selected for mutation operation φ; the fuzzy entropy of professional title structure, educational background structure, and age structure is taken as the objective function.

According to the analysis of Figure 3, the mutation operation threshold is 0 φ. This indicates that the small selection of the algorithm is not enough to increase the

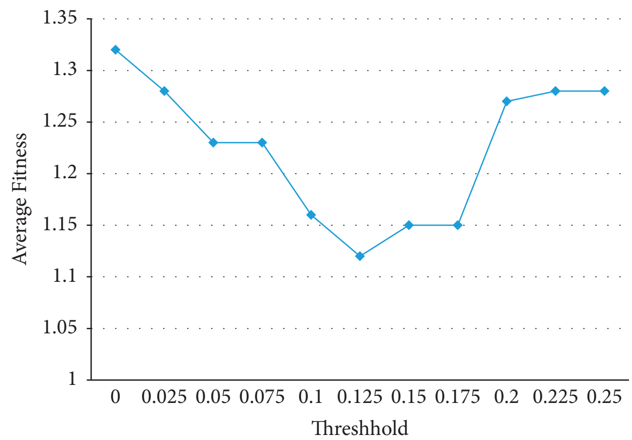

Figure 3: Influence of threshold on experimental results in mutation operation.

Table 1: Part of multiobjective optimization (solution 1) results.

		Solution 1			
Age	Education	Professor	Associate professor	Lecturer	Assistant
<30	Doctor	1.26	3.53	3.30	1.90
	Master	0.21	1.97	2.85	0.30
	Bachelor degree or below	0.07	0.57	0.55	0.03
30–40	Doctor	11.74	3.20	3.88	1.88
	Master	5.12	0.19	0.61	0.23
	Bachelor degree or below	0.10	0.22	0.04	0.02
40–50	Doctor	8.06	8.34	4.82	4.42
	Master	3.73	2.06	0.07	2.04
	Bachelor degree or below	0.68	1.38	0.02	0.07
>50	Doctor	3.61	3.75	4.55	1.25
	Master	0.52	1.79	3.87	0.22
	Bachelor degree or below	0.40	0.71	0.44	0.02

diversity of the population and improve the spatial search ability of the algorithm. The BPSO with mutation operation is equivalent to random sampling when the selection is larger, and the characteristics of the algorithm itself are masked.

During the experimental work, I have selected 0.125 as the threshold of mutation operation. I have selected two groups from BPSO Pareto optimal solution, which are listed in Tables 1 and 2. According to the characteristics and rationality judgment of the optimization of the teaching staff in colleges and universities, a group of optimal solutions close to their situation can be selected as the goal of the structural planning of the teaching staff. For this purpose, I have obtained two solutions such as solution 1 and solution 2 in Tables 1 and 2, respectively. If solution 1 listed in Table 1 is selected as the result of multiobjective optimization, then the proportion of professors, associate professors, lecturers, and teaching assistants is 36.6%, 28.8%, 24.2%, and 12.4%, respectively.

Similarly, the solution 2 is listed in Table 2; the proportion of graduate students, undergraduate students, and junior college students is 69.5%, 25.8%, and 4.7%, respectively. The proportion of people under 30 years old, between 30 and 40 years old, between 40 and 50 years old, and over 50 years old is 16.1%, 27.7%, 35.6%, and 20.6%, respectively. It can be seen that the structure of teaching staff after multiobjective optimization meets the requirements of the construction of teaching staff in colleges and universities.

Figure 4 illustrates the result obtained during first solution, i.e., solution 1, of my experimental work. From this figure, it is cleared that high proportion can be achieved during the teaching staff having ages ranging 30–40 years. This proportion lies between 16 and 18; the lowest proportion was achieved below the age of 30 years.

Figure 5 illustrates the result obtained during our solution 2 of my experimental work. From this figure, it is cleared that high proportion can still be achieved during the teaching staff having ages ranging 30–40 years. This proportion lies between 16 and 18, the lowest proportion achieved below the age of 30 years. It is clear that proposed planning structure of teaching staff after multiobjective optimization meets the requirements of the building of teaching staff in colleges and universities.

Table 2: Part of multiobjective optimization (solution 2) results.

		Solution 2			
Age	Education	Professor	Associate professor	Lecturer	Assistant
<30	Doctor	1.13	0.17	5.08	0.63
	Master	0.41	0.10	1.35	0.46
	Bachelor degree or below	0.18	0.02	1.34	0.50
30–40	Doctor	10.16	3.83	10.32	5.18
	Master	4.52	3.29	5.08	0.66
	Bachelor degree or below	2.43	0.04	0.01	0.01
40–50	Doctor	4.04	6.99	4.19	0.32
	Master	0.96	2.66	0.93	0.20
	Bachelor degree or below	0.09	0.28	0.25	0.08
>50	Doctor	4.70	8.66	2.04	2.92
	Master	0.17	0.04	0.59	1.82
	Bachelor degree or below	0.02	0.09	0.30	0.4

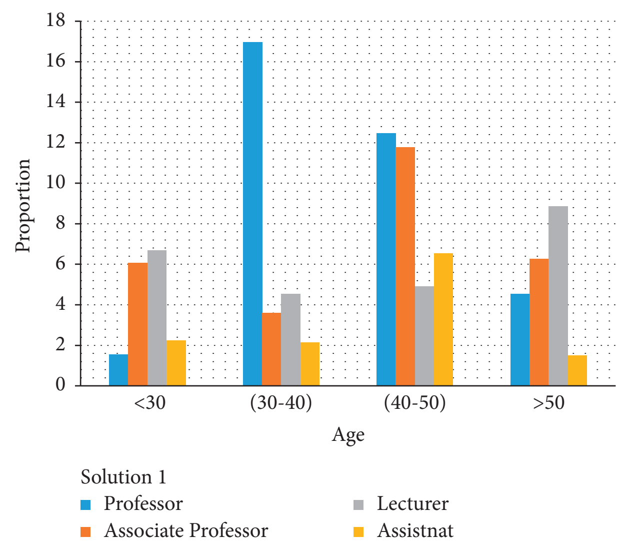

Figure 4: Comparison of proportion of ages >30 to ages<50 for solution 1.

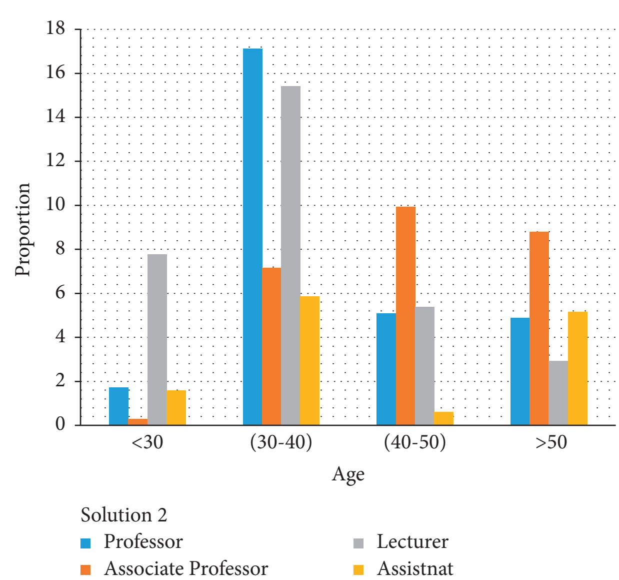

Figure 5: Comparison of proportion of ages >30 to ages<50 for solution 5.

5. Conclusion

Based on the study of the planning objectives of the construction of teaching staff in colleges and universities, this paper puts forward several objective functions and constraints for the construction of teaching staff from different aspects. These aspects include professional title structure, education background structure, and age structure. So, to solve the multiobjective structural optimization problem in the planning structure of teaching staff, this research work has used fuzzy entropy to calculate the title structure, education structure, and age structure and used them as the objective function of evaluation. Besides, I have used the multiobjective genetic algorithm NS-GA-II to optimize each objective function. My proposed system enables us to effectively improve the scientific and rationality of the construction and planning of the teaching staff by selecting the requirements of the medium- and long-term development plan of colleges and universities. My proposed system also provides a scientific basis for planning the construction goal of the teaching staff of colleges and universities.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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Research Article

Energy Efficiency Analysis of Wireless Sensor Networks in Precision Agriculture Economy

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Wireless sensor network (WSN) can play an important role during precision agriculture production to promote the growth of the agricultural economy. The application of WSN in agricultural production can achieve precision agriculture. WSN has the biggest challenge of energy efficiency. This paper proposes a model to efficiently utilize the energy of sensor nodes in precision agriculture production. The proposed model provides a comprehensive analysis of the precision agriculture. The model focuses on the characteristics of WSN and expands its application in precision agriculture. In addition, this paper also puts forward some technical prospects to provide a good reference for comprehensively and effectively improving the overall development level of precision agriculture. The paper analyzes the applicability and limitations of the existing sensor networks used for agricultural production technology. The ZigBee and Lora wireless protocols are utilized to have the best power consumption and communication in short distance and long distance. Our proposed model also suggests improvement measures for the shortcomings of existing WSN in the context of energy efficiency to provide an information platform for WSN to play a better role in agricultural production.

1. Introduction

Agriculture has always been an important pillar industry in the process of China's economic construction. Because of the existence of excessive fertilization in agricultural production activities, some phenomena such as farmland pollution, environmental deterioration, and biodiversity destruction have been brought into consideration [1]. These factors seriously affect the production, growth, and economic construction of the agriculture field. To promote the sustainable development of modern agriculture, the advanced scientific production technology is required to be considered along with good management of agricultural production activities. In the process of precision agriculture, the use of WSN can play a significant role in the context of energy efficiency. Precision agriculture is a management strategy in the process of agricultural production. It uses information technology reasonably and continuously improves the output and quality of agricultural production [2]. It also reduces the degree of environmental pollution and waste of energy and resources. The resources include energy and water. It improves the accuracy and modernization of agricultural production.

In China, the development of precision agriculture is still in the exploratory stage and faces many key technical problems. It is necessary to scientifically adopt modern monitoring means and fully control the use of pesticides and fertilizers. Moreover, proper monitoring and control are also required [3, 4]. At present, precision agriculture is still in the early stage of exploration and faces many key technical problems to be solved. For instance, the use of chemical fertilizers and pesticides can greatly improve food production. It is observed that the lack of scientific monitoring for soil fertility, plant diseases, and insect pests can affect the plants badly. In addition, the lack of fast and effective perception technology and equipment can also lead to the poor food production process. Moreover, the blind use of chemical fertilizers and pesticides may not only cause a lot of waste of resources but also bring serious soil and environmental pollution. Due to the variety and high cost of applied sensors needed in precision agriculture to overcome these challenges, the product has not yet achieved market scale due to the lack of standardization research. At present, there are many restrictive factors in the use of agricultural sensors, such as diversified conditions, bad working environment, insufficient power supply, and short service life. Moreover, the agricultural production base is far away from the city due to which the public information and communication infrastructure are poor and the cost of special communication means is high. There are spectrum compatibility and interference problems as well.

WSNs are utilized for the measurement of temperature, monitoring the environment, measurement of irrigation system, and measurement of water supply in agricultural applications. WSNs support the farmers to generate high quantity crops. However, they require a battery power supply to provide energy to sensor nodes. These networks increase the quality and production of the crops which directly affect the economy. Recent studies have found that many problems in the implementation of precision agriculture will be gradually solved with the application and development of these networks. The application of wireless sensor network in agriculture is one of the most favorable methods to achieve precision agriculture, improve the yield of food crops, and reduce the burden of farmers. The use of WSN is significant for ensuring the healthy growth of crops to achieve precision agriculture [5, 6]. It can minimize the use of pesticides, effectively control weeds and pests, and achieve efficient green precision agriculture. WSN can sense and collect real-time data of various information changes in the process of agricultural production and provide timely feedback to the users. The data analysis and processing results are forwarded to users to realize the efficient management of precision agriculture.

This paper discusses the development potential of WSN in agricultural production from the communication protocol perspective. The paper focuses on the characteristics of WSN and expands its application in precision agriculture. In addition, the paper also puts forward some technical prospects to provide a good reference for comprehensively and effectively improving the overall development level of precision agriculture. The paper further analyzes the applicability and limitations of the existing sensor networks used in agricultural production technology.

The rest of this paper is organized as follows. In Section 2, the background studies in the context of our work are presented. In Section 3, our proposed design for moisture monitoring and automatic water-saving irrigation system is discussed. In Section 4, we discuss our monitoring and early warning of diseases and insect pests. In Section 5, simulation results are provided followed by concluding remarks in Section 6.

2. Background and Related Work

During the rapid deployment of WSN technology, the battery power supply with sensor nodes is mainly used as an energy supply [7, 8]. The WSN is a collection of detached and devoted sensors that observe and record the semantic state of the surroundings and transfer the recorded information to a principal site. WSN architecture and the detailed structure are shown in Figure 1. Battery-powered WSN consists of sensor nodes, processors, and radio frequency (RF) modules. The sensor node can communicate wirelessly through the communication link and forward its data to the base station or coordinator node through the gateway communication. A node is used to collect, compute, and communicate the data and information with its associate nodes in a particular network. The communication can collect information from various sensors in sensor nodes from simple (i.e., humidity, pressure, and temperature) to complex (i.e., positioning, tracking, microradar, and image) and then combine and transmit it to the wireless sensor network to realize real-time monitoring of WSN. Therefore, the sensor nodes have the function of monitoring, storing, and processing information in the whole monitoring process [9]. The communication will send the information to the WSN to implement the real-time monitoring function. WSN has a wide range of application effects to obtain sufficient and accurate environmental information in the process of precision agriculture. WSN includes three major components: base station, sensor node, and sink node [10–12].

The sensor node has the ability to communicate and compute. The connection process adopts the form of short-range wireless, which can form a multihop wireless network. The introduction of wireless sensor network into precision agriculture can fully monitor the growth data of crops, comprehensively obtain the agricultural environment information, and support the steady development of precision agriculture activities [13, 14]. WSN itself has low power consumption, simple use, and low cost. It can adapt to the agricultural production environment and has long-term stable performance. It can design some data acquisition algorithms with modern agricultural characteristics to significantly improve the speed of data acquisition and support the smooth development of precision agriculture activities. Currently, WSN is extensively utilized in monitoring the agriculture field to advance the quality of service (QoS) and enhance the production of farming. In this agriculture field, the sensors collect diverse kinds of information (e.g., CO2 level, humidity, and temperature) in instantaneous situations.

The WSN can not only realize precision agriculture and improve agricultural yield but also be used in other agricultural applications. It can be utilized for soil nutrient data to predict the health status of crops and the quality of agricultural products [15, 16]. In addition, it can also be utilized for predicting irrigation planning by observing weather conditions (such as temperature and humidity) and soil moisture. Relevant sensor nodes can be added to the existing WSN to improve the parameter agricultural monitoring system and expand the network. However, there are some problems in the application of WSN in agriculture, such as determining the best deployment scheme, measurement cycle, routing protocol, communication range, scalability, and fault tolerance [17]. The decentralized deployment of sensor nodes requires a long time of data collection, and the communication link may be weakened or

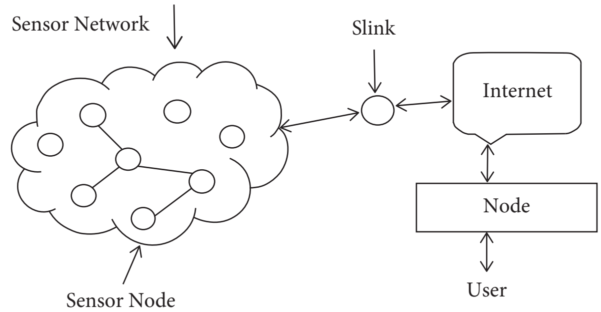

Figure 1: Schematic diagram of wireless sensor network architecture.

lost due to signal attenuation. The sensor nodes in wireless sensor networks are powered by battery, which is limited to the limited battery power, so there are some problems in WSN, such as power consumption and battery life extension. Although the application of WSN has been increasing for many years, the application of WSN is limited due to the slow development of the battery manufacturing industry [18]. UAV or UAV can be connected with the base station to establish mobile data connection service to meet the requirements of the battery power amplifier and solve the problem of the long distance between farm and base station. This connection allows sensor nodes to relay their data to the base station in the farmland area, which can buffer the limit of the wireless sensor battery.

The Internet of Things (IoT) is the revolution of the Internet, which connects all things that can be connected. The development of mobile cellular network technology plays a vital role in the field of IoT. Narrowband Internet of Things (NB IoT) is a new IoT system based on the current development of cellular network LTE function [19]. Narrowband IoT can share the LTE spectrum without interference and can use the same device to connect to LTE main network seamlessly, supporting all network facilities, such as security, tracking, policy, billing, and authentication [20]. NB IoT has very low power consumption, which can extend the battery life for 10 years. The design goal of narrowband IoT has the characteristics of low power consumption, wide coverage, many connection points, low cost, and so forth. In the near future, NB IoT technologies such as long-distance radio Lora and SIG fox will play an increasingly important role in agricultural IoT due to their advantages of low power consumption and long-distance transmission. The WSN has a wide range of applications including the agriculture production where it is extensively utilized in monitoring the agriculture field to advance the quality of production of farming. However, the battery power supply with sensor nodes is mainly used and efficient utilization of the energy is one of the big challenges during the rapid development of WSN technology.

3. Design of Moisture Monitoring and Automatic Water-Saving Irrigation System

This section provides the proposed design for moisture monitoring and water-saving irrigation system. The proposed system is designed taking into consideration the fact that Xi'an city is rainy in summer and dry in winter and has abundant sunshine that is prone to drought and flood. The average water resources per capita of the city are less than 500 cubic meters that is lower than the national average level. Based on this, a water-saving irrigation control system based on WSN is designed, and the system is mainly composed of low-power wireless sensor network nodes through ZigBee ad hoc network [21, 22]. The soil moisture information parameters to be monitored include soil water potential, soil moisture content, air temperature, relative humidity, and groundwater level. The sensor used is a four-channel temperature and humidity transmitter. Through the signal value measured by the sensor, the information parameters can be calculated by the empirical formula. A detailed description of the proposed design is provided in the upcoming subsections.

3.1. Design of Automatic Water-Saving Irrigation System for Farmland. The agricultural irrigation system based on WSN consists of four parts that are sensor node group, receiving node, irrigation controller, and irrigation pipe network as shown in Figure 2. The sensor nodes carrying soil moisture are deployed according to the planting status and irrigation status of farmland to form an irrigation node group. Each node is responsible for monitoring the soil moisture in a small area. The irrigation area node group and the receiving node constitute a typical WSN, using ZigBee wireless data transmission technology. The sensor data are uploaded to the receiving node in the form of wireless multihop. The automatic water-saving irrigation system is to lay an irrigation pipe network on the farmland in the irrigation area and install an electric control valve on the pipe. The overall system would be more flexible if the water-saving irrigation control is flexible. The automatic water-saving irrigation can be transformed on the basis of the original irrigation pipe network. The original irrigation pipe network can be installed with an electric control valve to make better use of the original irrigation pipe network and reduce investment. In the area covered by WSN, the irrigation controller can spray irrigation in specific areas according to the sensor information. The proposed system includes a particular module that is responsible for the supervision of the entire network. The proposed Automatic Water-Saving Irrigation System is basically based on sensor-free network.

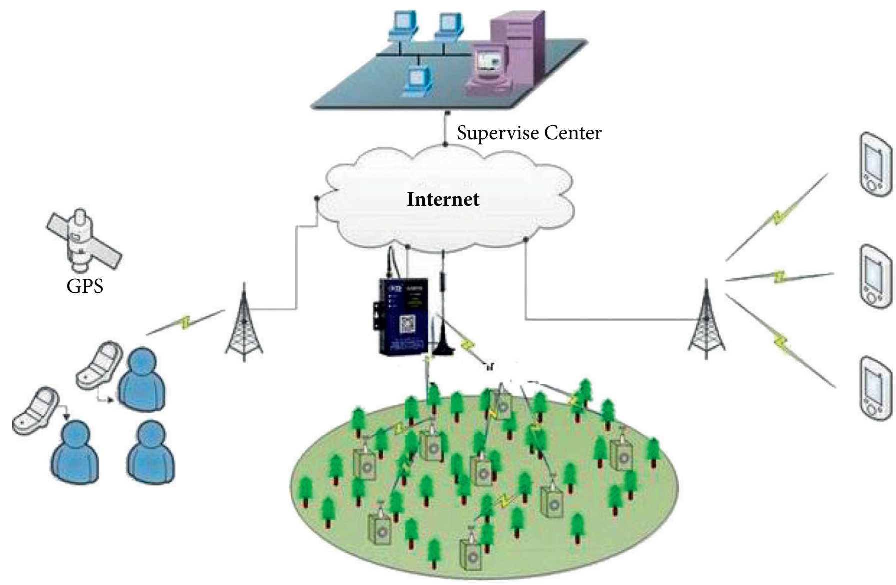

Figure 2: Automatic water-saving irrigation system based on sensor-free network.

3.2. System Function Module. The hardware structure of the sensor node realized in the proposed design is discussed in this section and shown in Figure 3. The hardware structure is mainly composed of controller module, sensor module, ZigBee protocol communication module, and solar self-powered module.

3.3. Design of Irrigation Controller. S3c2410arm9 development board of embedded system is used as the mainboard to constitute the irrigation controller. The receiving node transmits information through a serial port and processes the control information. An electric control valve is controlled by an I/O port. S3C2410 has 117 multifunction I/O ports. The system has high scalability. The WSN periodically detects the humidity (the period is 10 s) and uploads it to the irrigation controller. When the irrigation controller finds that the humidity detected by the WSN nodes in a certain area is lower than the specified value, it turns on the electric control valve of the pipe network in the area for sprinkling irrigation. When the soil humidity in the area rises to a certain value, the system will start sprinkling irrigation and close the electric control valve of the pipe network in this area to stop sprinkling.

4. Monitoring and Early Warning of Diseases and Insect Pests

The Huainan City environment is taken into consideration to issue the early warning. The warning is concerned with diseases and insects pests. The planting patterns of Huainan City are basically one rice, one wheat (water and drought mixed cropping pattern), or one bean. Wheat and rice sheath blight are the main common diseases of grain crops in Huainan City. There is an information chain of data collection to data submission and management, then data processing and forecasting, and finally the pest forecasting information release in the content of pest monitoring and early warning. The information chain is also shown as follows:

Data collection⟶data submission and management

Data submission and management⟶data processing and forecasting

Data processing and forecasting⟶pest forecasting information release

Each link of the information chain is corresponding to the technology of data acquisition, data transmission, data processing, and data application in information technology.

4.1. Associated Technologies. The technologies related to monitoring and early warning are discussed in this section. Each link of the pest monitoring and early warning information chain involves sensor technology, database technology, expert system technology, artificial neural network technology, global positioning technology (GPS), geographic information system technology (GIS), network technologies, and communication technology. Among them, the automatic counting of microinsects mainly uses computer image processing technology to solve the problems of difficult investigation and data acquisition. The automatic recording device of insect trapping is to count the number of insects through scanning grating by using the attraction of sex attractant. Pad and GPS data acquisition and recording technology are mainly used for manual investigation of conventional diseases and insect pests. It is used to record the data and GPS positioning information at the same time. The field microclimate data are also recorded at the same time that is closely related to the occurrence of diseases and various pests. The field microclimate data monitoring technology mainly uses sensor technology and GPRS network communication technology to automatically obtain real-time microclimate data. The data are relevant to diseases and various pests and transmit them to the database for standby.

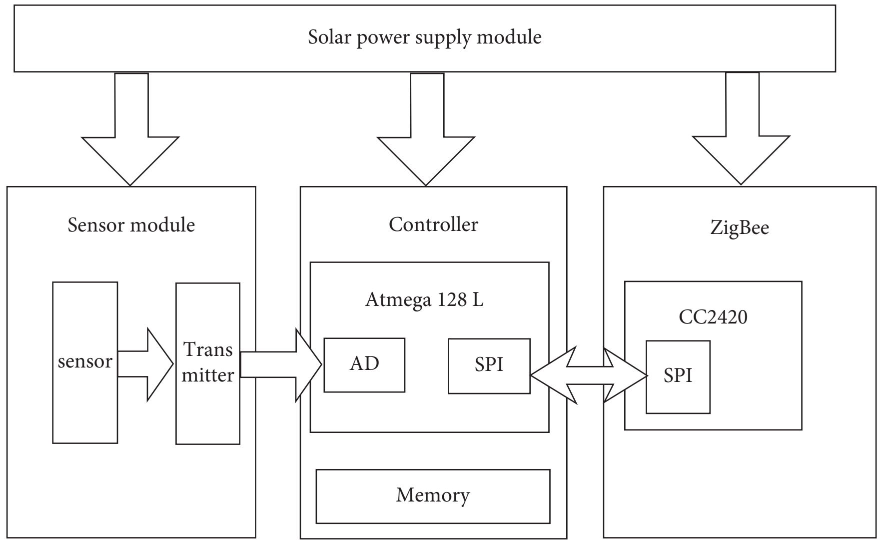

Figure 3: Hardware structure of sensor node.

4.2. Technical Assembly and Matching. The data collection technologies (the main data sources of the proposed system) are assembled with data transmission technology. It can provide real-time and reliable monitoring data of diseases and pests and microclimate for the data management system. Insect pests and environmental factors in the data management system are considered as the input of the expert system. The inference engine of the expert system is driven to forecast the diseases and insect pests, and the forecast information is released through the forecast information release system to guide the plant protection work.

5. Simulation Analysis of Precision Agriculture Effect

The simulation analysis is performed in this section for the precision agriculture effect. In order to master the growth status of animals and plants and improve the scientific management level, it is necessary to monitor the specific physiological and ecological indicators of animals and plants. In the past, the monitoring methods were relatively backward, which affected the growth control activities of animals and plants. At this stage, WSN is actively introduced in the process of precision agriculture production, which can automatically sense the state of crop growth link at a lower cost. In addition, an intelligent system is used to accurately monitor, analyze, and record the physiological and ecological parameters of animals and plants that provide a good premise for effectively improving the efficiency of monitoring work as shown in Figures 4 and 5.

The lack of water resources is an important factor for restricting the current economic growth, but there is a serious waste of agricultural water. It is necessary to strengthen the research work of water-saving irrigation. The good application of WNA (Wireless Network Agriculture) is the monitoring of water during the process of crop growth and comprehensively monitoring of the actual water and soil moisture in the irrigation area. The WNA is basically a simple WSN (Wireless Sensor Network) that is utilized for agriculture applications and production. It also formulates a scientific and effective irrigation scheme combined with the development of these crops. However, it should be noted that the application of WSN in agricultural production is not widespread, mostly in a small-scale production environment such as tea garden, orchard, and greenhouse, and further research. The development is needed in large-scale farmland production.

It is evident from Figure 4 that agricultural irrigation based on wireless sensor network has played a very good role in water saving with the increase of time. It is necessary to monitor the specific physiological and ecological indicators of animals and plants for mastering the growth status of animals and plants to improve the scientific management level. In the past, the monitoring methods were relatively backward, which affected the growth control activities of animals and plants. At this stage, WSN is actively introduced in the process of precision agriculture production, which can automatically sense the state of crop growth link at a lower cost. In addition, an intelligent system is used to accurately monitor, analyze, and record the physiological and ecological parameters of animals and plants that provide a good premise for effectively improving the efficiency of monitoring work.

Figure 5 reveals that the energy efficiency of precision agriculture based on WSN is far lower than that of traditional agriculture according to the data from January 2020 to May 2021.

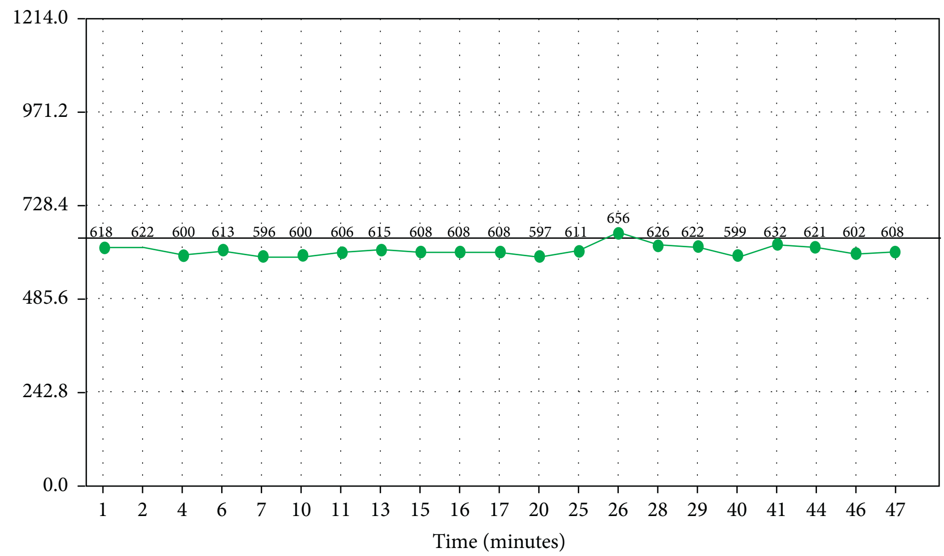

Figure 4: Change curve of agricultural irrigation water.

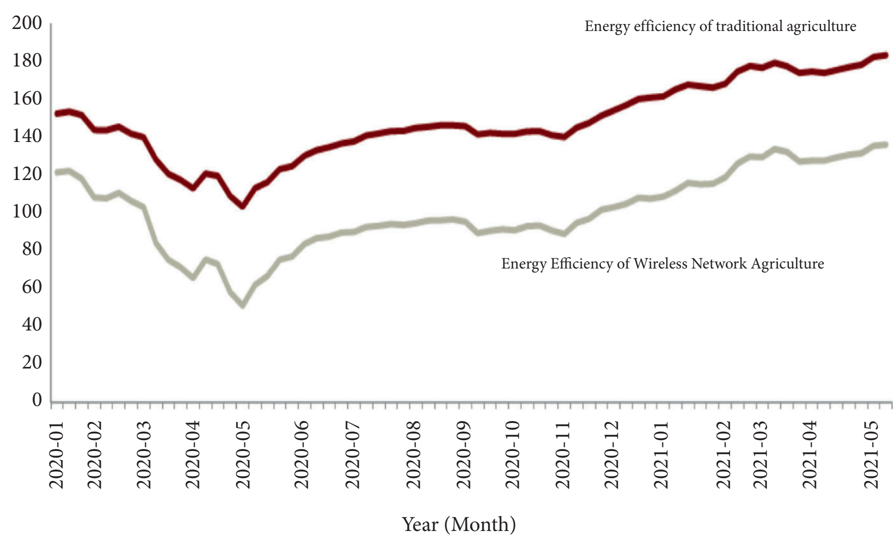

Figure 5: Energy efficiency analysis of physiological and ecological parameters.

6. Conclusion

Wireless Sensor Networks (WSNs) have the biggest challenge of energy efficiency. This paper suggests a scheme to efficiently utilize the energy of WSN in precision agriculture production. The proposed model aims to bring improvement measures for the shortcomings of existing WSN in the context of energy efficiency to provide an information platform for WSN to play a better role in agricultural production. WSN can play an important role in the growth of the agricultural economy. It is evident from the results that WSN can achieve precision agriculture by improving accuracy and efficiency and reducing the cost of wireless protocol systems. Precision agriculture can use the agricultural automation system to improve the management mode and improve the production efficiency.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Research Article

Quality Evaluation Method of a Mathematics Teaching Model Reform Based on an Improved Genetic Algorithm

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The poor comprehensiveness of the evaluation indexes of quality evaluation methods for the traditional college mathematics teaching model reform results in low accuracy of the evaluation outcomes. In this paper, aiming at this problem, a quality evaluation method for the college mathematics teaching model reform, based on the genetic algorithm, is proposed. The simulated annealing algorithm uses the weighted comprehensive objective evaluation multiobjective optimization effect that can effectively improve the accuracy of the evaluation results. In the training process, the gradient descent back-propagation training method is used to obtain new weights for the quality evaluation of college mathematics teaching mode reforms and to score various indicators and evaluate the indicators. The mean value of the outcomes is the result of mathematics teaching quality evaluation. The experimental results show that the training error of the convolutional network of the proposed method is significantly small. Based on the genetic algorithm that improves the convolutional network training process, the obtained quality evaluation outcomes are higher in accuracy, better in goodness of fitness function, and considerably lower than other state-of-the-art methods. We observed that the improved genetic algorithm has a more than 90% goodness of fit and the error is significantly lower, that is, 0.01 to 0.04, than the classical genetic algorithm.

1. Introduction

With the continuous adjustment of college talent training goals, college mathematics education and teaching have changed from the early learning of basic theoretical knowledge system to the ability of mathematics innovation and application. Under these circumstances, the content and form of mathematics education and teaching in colleges and universities need to be optimized to meet the requirements of innovation and practice in mathematics education and teaching in the new era. Affected by the traditional teaching concepts and other factors, the content and form of mathematics education and teaching in China's colleges and universities have not been innovated with the development of society, which has caused college students to lack interest in mathematics classroom teaching. Therefore, students' enthusiasm and initiative to participate in classroom teaching are relatively high to low. Traditional mathematics teaching is mainly based on the basic theoretical knowledge, but this ignores the cultivation of college students' practical application ability in mathematics. For these reasons, college students cannot adapt to the actual needs of social development, which affects the overall development of college students and provides less employment opportunities for college students [1]. In response to this problem, college mathematics education and teaching should take the needs of mathematics professionals in the new era of social development as the starting point, enrich the teaching content, innovate mathematics education and teaching methods, strengthen the training of college students' mathematics practice and application ability, and promote college students' comprehensive mathematics literacy.

High-quality teaching is not only the fundamental purpose of the college or university but also the basic task of all educational institutions including colleges and universities, and it is also the foundation of all educational institutes. Colleges and universities must strictly establish the long-term concept of "survive by quality and develop by quality," supervise and control the quality of teaching, focus on teaching observation and evaluation, and continue to provide talents for the society [2]. Nowadays, with the continuous development and updated technologies in colleges and universities, the teaching reform can become more dynamic, and the effective use of Internet along with the education technology can also expand teachers and students to a certain extent [3]. Few researchers have already investigated this issue, but they still failed to provide an effective solution and reform model.

Literature [4] aimed at the evaluation of classroom teaching quality in colleges and universities and proposed an auxiliary teaching quality evaluation model based on active learning support vector machines. Comprehensive consideration of various actual conditions is used in constructing an evaluation index system for classroom teaching quality. Adopting active learning support vector machine establishes a classroom teaching quality evaluation model. Literature [5] designs a university teaching quality evaluation model based on data mining algorithms. This model first studies and analyzes the current literature on teaching quality evaluation in universities and establishes the impact of university teaching quality evaluation factors. Next, the model collects data based on those factors that may affect the teaching quality of colleges and universities. The authors then use experts to determine the teaching quality level of colleges and universities and establish learning samples for college teaching quality evaluation. Finally, the BP neural network of the data mining technology is introduced to train the learning samples to form the teaching quality of colleges' and universities' evaluation model.

In the process of evolution, the feasible solution set of genetic algorithm retains the better solution with the corresponding objective function value with a certain probability through the selection operation. Moreover, this eliminates the corresponding solution with the worse objective function value and constructs it through the crossover operation and the mutation operation. In this way, the entire feasible solution set can gradually get closer and closer to the global optimal solution through continuous iteration and evolution [6]. When the whole algorithm is over, decode the most adaptable individuals in the last generation of the population for an optimized feasible solution. Internet technology has spread to all corners of people's lives that not only brings convenience to people but also has a huge impact on traditional mathematics teaching models. The huge impact has also brought other advanced methods and platforms to the reform and time of meta solution that can be obtained.

In this paper, we propose a method for evaluating the quality of college mathematics teaching model reform based on an improved genetic algorithm. The basic process of genetic algorithm is described. On this basis, an improved simulated annealing algorithm is obtained by simulating the annealing process in physical thermodynamics. Furthermore, the main points of the reform of mathematics teaching mode in colleges and universities are analyzed, and the quality evaluation system of mathematics teaching mode reform is constructed. Then, we train the convolutional neural network through the simulated annealing algorithm and use the convolutional neural network optimized, through the simulated annealing algorithm, for evaluation and learning. Finally, we apply it to the evaluation of mathematics teaching quality in colleges and universities. The convolutional neural network training divides the quality of mathematics teaching into different indicators to carry out evaluation. The inputs of these indicators are then fed into each convolutional network, which scores each indicator. We then use the average of the evaluation outcomes obtained through these indicators as the result of the entire mathematics teaching quality evaluation model. The following are the main innovations points of the research presented in this manuscript:

(1) Improving the traditional genetic algorithm by simulating the annealing process in physical thermodynamics
(2) Analyzing the reform content of mathematics teaching mode in colleges and universities
(3) Formulating the quality evaluation system of mathematics teaching mode reform according to the reform content
(4) Using genetic algorithm to improve the convolutional neural network.

The structure of the remaining part of this paper is as follows: Section 2 describes the details of the related work in the context of genetic and simulated annealing algorithms. In Section 3, we discuss the evaluation of the reform quality of mathematics teaching mode in colleges and universities based on an improved genetic algorithm. A new variant of the genetic algorithm is suggested. Section 4 is about experimental setup and results. Finally, Section 5 concludes this paper along with directions for further research and investigation.

2. Improved Genetic Algorithm

2.1. The Basic Process of the Classical Genetic Algorithm. The standard genetic algorithm generally includes three basic operations, that is, (1) a selection operation, (2) crossover operation, and (3) mutation operation [7]. These operations are briefly described in subsequent paragraphs.

(1) The main purpose of the selection operation is to select individuals with good performance and eliminate individuals with the poor performance. At the same time, to keep the size of the population unchanged, it consists of two steps: (i) first, calculate the fitness value of everyone in the population and (ii) then select individuals in the population based on the fitness value according to a certain method.
(2) The selection operation is just to copy the individuals with good performance so that they can occupy a larger proportion in the population and eliminate the individuals with poor performance from the population, and this process does not create any new individuals. The crossover operation is to generate a

new individual by exchanging part of the genetic information possessed by the two parent individuals according to certain rules. To keep some well-behaved individuals in the population intact, not every individual will participate in the crossover operation [8]. In the actual operation, first, generate a random number within the range of 0 to 1 and then judge whether the value of this random number is greater than the crossover's preset probability. In case the value is smaller than the threshold values, then the selected individual will participate in the crossover operation, otherwise not.

(3) The performance of the offspring individuals generated by the crossover operation may not be better than that of the parent individuals. This is due to the fact that the effective gene is missing, and the algorithm falls into a local optimal solution. To overcome this situation, it is necessary to perform mutation operations on some individuals in the population, that is, to change their own structure to a certain degree according to certain rules, so that the offspring individuals can show the traits that the parent individuals do not have. The standard genetic algorithm mainly has the following steps, as illustrated in Algorithm 1. The flowchart of the standard genetic algorithm is shown in Figure 1.

2.2. Principle and Basic Process of the Simulated Annealing Algorithm. The simulated annealing algorithm is a general probabilistic heuristic algorithm, which is a simulation of the annealing process in physical thermodynamics and is used to search for the global optimal solution of the optimization problem in a huge solution space. The standard simulated annealing algorithm mainly has the steps as illustrated in Algorithm 2. The flowchart of the standard simulated annealing algorithm is shown in Figure 2.

It can be seen from the process in Figure 2 that the following factors affect the outcomes of the algorithm. The simulated annealing algorithm has the following major advantages over the classical genetic algorithm:

(1) The initial value is very robust, which reduces the quality requirements for the initial solution
(2) With progressive convergence, the algorithm can finally converge to the global optimal solution with a 100% probability
(3) It is potentially very easy to implement and has a wide range of applications in other fields

3. Evaluation of the Reform Quality of Mathematics Teaching Mode in Colleges and Universities Based on an Improved Genetic Algorithm

In this section, we briefly describe the methods of optimizing mathematics teaching and optimize them using an improved variant of the classical genetic algorithm.

3.1. Analysis of the Reform of Mathematics Teaching Mode in Colleges. For higher mathematics, the reform of mathematics teaching mode can play an important role in cultivating students' logical thinking and practical abilities. For the current education, if the teacher only knows to blindly pay attention to the theoretical aspects of teaching, it will make the students' understanding and thinking ability in the classroom very rigid, and therefore, they will only blindly follow the teacher's footsteps to learn the basics. Therefore, in such circumstances, the innovative thinking abilities of the students cannot be cultivated. The reform of mathematics teaching mode in educational institutes including colleges and universities mainly includes the contents that are discussed in subsequent subsections.

3.1.1. Methods of Optimizing Mathematics Teaching and Training Concepts. The injecting teaching method is a widely used and well-known methodology in mathematics teaching of colleges and universities. Under the background of the current new era, traditional teaching methods should be effectively changed and updated [9]. On the one hand, colleges and universities should abandon the original theoretical and test-oriented teaching models and cultivate students' innovative ability and application ability to adapt to social development as the current teaching goal. On the other hand, to make the teaching content practical, a diversified teaching system should be continuously constructed and some practical teaching methods and evaluation methods need to be infiltrated into the teaching content to ensure quality to a certain extent. The teaching content can be linked to the actual life and then lay a solid foundation for the future development of the students.

3.1.2. Effectively Optimize the Teaching System. In this regard, it is essential to understand the characteristics of the instrumental subjects of higher mathematics, to reform the syllabus and teaching content. Furthermore, it is also needed to make the students' majors and characteristics that can coordinate and cooperate with each other. In this way, the importance of mathematics could possibly be strengthened. In addition, in the construction of the teaching system, it is necessary to ensure the subjectivity of students in teaching, and it is also necessary to effectively stimulate the enthusiasm of students in the process of teaching and then enhance the initiative of students. In the teaching of advanced mathematics, teachers should vigorously encourage students to think, and fully understand the class within the classroom activities, to choose different teaching methods for different students, and effectively improve the quality of teaching.

3.1.3. Effectively Reform the Current Teaching Evaluation and Assessment Methods. At present, the main method of evaluating mathematics teaching in domestic colleges and universities is the evaluation of students' performance. Under the new situation, the method of teaching reform must break through the traditional one-size-fits-all teaching evaluation method [10]. For example, in the assessment of

Step 1: randomly generate several initial feasible solutions according to a certain method and use the set of them as the initial population.
Step 2: evaluate everyone in the population, calculate their fitness value, and then determine whether it meets the optimization criteria of the algorithm. If it does, the current best-performing individual is the optimal solution and output solve the results and end the algorithm; otherwise, go to Step 3.
Step 3: according to the fitness of the individuals in the population, use a certain method to select the survival of the fittest in the population. The greater the fitness of the individual, the more likely it is to be selected; otherwise, the more likely it is to be eliminated.
Step 4: use a certain method to perform crossover operations on the population with the set crossover probability.
Step 5: use a certain method to perform mutation operations on the population with the set mutation probability.
Step 6: go to Step 2.

Algorithm 1: The standard genetic algorithm.

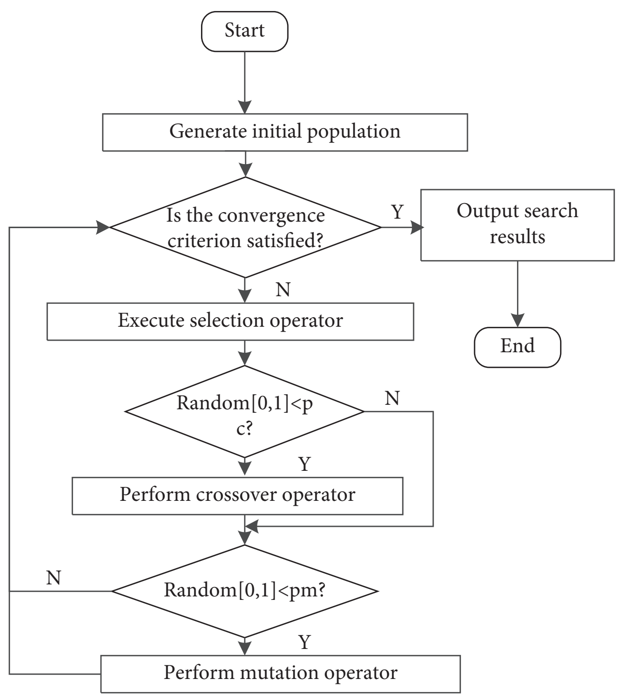

Figure 1: The flowchart of the standard genetic algorithm process [7].

Step 1: set the initial temperature t_0, generate an initial feasible solution x_i according to a certain method, and calculate its corresponding energy value $E(x_i)$.
Step 2: determine whether the termination condition of the outer loop is satisfied. If it is satisfied, the current optimal solution is the required optimal solution. Hence, output the result and end the algorithm; otherwise, go to Step 3.
Step 3: determine whether the termination condition of the inner loop is met; if it is met, then update the temperature of the system and go to Step 2; otherwise, go to Step 4.
Step 4: starting from the current solution x_i, generate a new feasible solution x_j according to a certain method and calculate its corresponding energy value $E(x_j)$.
Step 5: if $E(x_i) > E(x_j)$, then accept x_j as the current optimal solution; otherwise, accept x_j as the current optimal solution with probability $\exp[E(x_i) - E(x_j)/kt]$.
Step 6: go to Step 3.

Algorithm 2: The standard simulated annealing algorithm.

students, it is necessary to add some practical skills exercises, which will make the assessment space wider, so that students can apply the knowledge content they have learned through practice and think to answer. In terms of assessment, there are certain differences among various students in the classroom, so teachers need to adopt different methods for

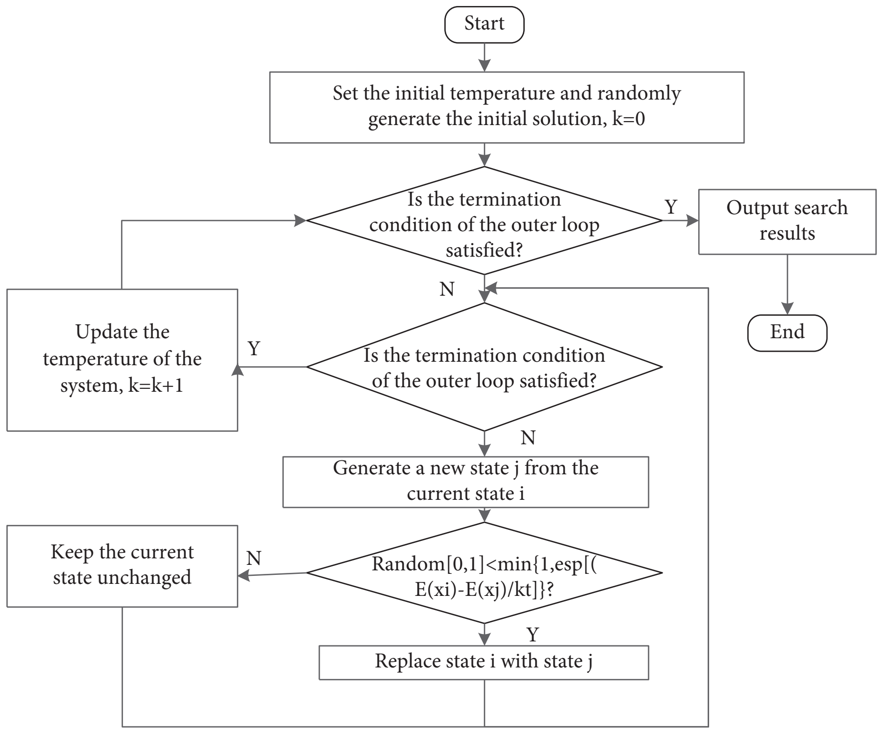

Figure 2: The flowchart of the standard simulated annealing algorithm flow [7, 8].

different students as appropriate to ensure fair assessment of the course catalog and teaching quality.

3.2. The Quality Evaluation System of the Reform of Mathematics Teaching Mode. The quality evaluation index system of mathematics teaching model reform is an important determinant of whether the quality evaluation of mathematics teaching model reform in colleges and universities is scientific, fair, and reasonable. The evaluation of the quality of mathematics teaching model reform in higher education schools is a very complex issue. The different types of courses and student types make it difficult to find a universally applicable mathematics teaching model reform quality evaluation system that can be used to evaluate the quality of teachers' mathematics teaching model reforms in all colleges and universities. For different types of higher education schools, according to their own development and future goals, they can adopt more targeted and more suitable evaluation indicators to make the mathematics teaching model reform quality evaluation system more accurate and scientific, and to improve the quality of the mathematics teaching model reform. The evaluation work plays a very important role. The rationality of the comprehensive evaluation results of the quality of mathematics teaching model reform can enable school leaders, administrations, and the staff of the mathematics teaching model reform quality evaluation management department. Moreover, this will also help all the teachers themselves to timely understand and discover the existence of their own mathematics teaching model reforms and make appropriate adjustments within time [11]. It has an irreplaceable effect on the development of colleges and universities, the cultivation of students, and the continuous improvement of teachers' mathematics teaching model reform.

The establishment of a quality evaluation system for mathematics teaching model reform should be a mathematics teaching model reform model and method that can promote individual development, respect commonality, pay attention to individuality, reflect the common law of mathematics teaching model reform, reflect the mathematics of different types and levels of college teachers, and the characteristics of teaching mode reform. Currently, the establishment of a diversified, reasonable, and distinctive mathematics teaching model to reform the quality evaluation standard system has a key role and significance [12]. It can eliminate the idleness and waste of educational resources in time and realize the effective allocation of resources based on the research results. The current mathematics teaching model reform quality evaluation system is based on the problems in the establishment process and follows the principles of comprehensiveness, directionality, motivation and improvement, objectivity, and subjectivity. For different types of courses, such as basic theory courses, the mathematics teaching model reforms practical courses, comprehensive courses, etc., according to the unified standards of the school. According to the characteristics of courses, subjects, grades, etc., using different evaluation indicators, or using different weights for evaluation, using artificial intelligence, etc. Note that the nonlinear problems are more objective evaluation methods and could improve the problems of the single evaluation type of teacher mathematics teaching model reform quality, the unreasonable proportion of evaluation indicators, and the strong subjective factors of evaluation methods [13]. Based on the above analysis, we construct the quality evaluation index system of mathematics teaching mode reform, as shown in Table 1.

As the output of the neural network, the quality evaluation outcomes of the mathematics teaching model reform are divided into five different grades: (a) excellent, (b) good, (c) intermediate, (d) pass, and (e) fail. The score ranges of each grade of the teaching quality evaluation outcomes, in this article, are shown in Table 2.

3.3. Construction of a Quality Evaluation Model for the Reform of Mathematics Teaching Mode Based on an Improved Genetic Algorithm. To sum up, the improved genetic algorithm, that is, simulated annealing algorithm, is used to evaluate the reform quality of mathematics teaching mode in colleges and universities. The steps of the simulated annealing algorithm are illustrated in Algorithm 3.

The simulated annealing algorithm uses weighted comprehensive targets to evaluate the effect of multi-objective optimization. Based on the randomness of the weights, through repeated or parallel operation of the algorithm, the optimal solution of the pareto boundary in each direction is obtained, and multiple selection targets are further assigned to the decision [14].

At this stage, the convolutional neural network has achieved certain results in the evaluation of teaching quality, which can effectively improve the accuracy of the evaluation results. In the evaluation of mathematics teaching quality, the convolutional neural network is trained through the simulated annealing algorithm, and the modified linear unit is used to obtain its operating function [15], namely:

$$C_{j+1} = \max\left(0, W_j \otimes C_j + B_j\right). \quad (1)$$

Among them, C_j describes the evaluation index value obtained in a particular convolutional network layer, i.e., j; W_j describes the weight value obtained when the convolutional layer is j; B_j describes the bias parameter of the convolutional neural network for layer j; $\otimes$ represents the convolution operation, which indicates the maximum extreme value of the running function, and the pooling method selects the maximum extreme value pooling to obtain

$$C_{j+1} = \max_R C_j. \quad (2)$$

Among them, R represents any pooling range in the evaluation index, while C_{j+1} represents the largest extreme value within the range.

The selected index data is fed into the convolutional neural network for network training purpose. Use the norm method, as given by equation (3), to set the loss function in the network training process.

$$J = \sqrt{\|f(x, W)\|^2}. \quad (3)$$

Among them, x represents the input training evaluation index; W represents the network weight; and $f(x, W)$ represents the input index x the convolutional network sends the evaluation score value. After minimizing J to train all convolutional nerves, the process uses the gradient descent back-propagation training method to obtain brand-new weights, as given by

$$\begin{aligned} \Delta_{i+1} &= m \times \Delta_i - \eta \times \frac{\partial L}{W_i^j}, \\ W_{i+1}^j &= W_i^j + \Delta_{i+1} - \lambda \times \eta \times W_i^j. \end{aligned} \quad (4)$$

Among them, m represents the momentum factor in the gradient descent backpropagation; η represents the learning probability; i represents the number of network training; Δ_{i+1} represents the gradient increment with i training times; and λ represents the weight attenuation value.

In the training process, we set the learning probability within the range of [0.001, 0.001]. After training, we take the weight of the last iteration as the weight value of the following and next mathematics teaching quality index evaluation.

Convolutional neural network training divides the quality of mathematics teaching into different indicators for evaluation and inputs these indicators into each convolutional network. Then the network scores each indicator, which is recorded as q_i, to obtain different indicator scores. Finally, we use the mean value of the index evaluation outcomes as the result of the whole mathematics teaching quality evaluation, as illustrated by the following equation:

$$Q = \frac{1}{N} \sum_{i}^{N} q_i. \quad (5)$$

Among them, Q represents the result of the mathematics teaching quality evaluation method, while all other notations are as described earlier.

4. Experimental Results and Analysis

4.1. Experimental Settings. To verify the effectiveness of the quality evaluation method of the college mathematics teaching model reform designed based on the improved version of the classical genetic algorithm, an online teaching course was selected as the test object. A total of 5,000 people attended the online teaching course. Students gave their feedbacks on the evaluation texts after completing the class. We refined the collected data through deleting useless evaluation texts and junk evaluation texts and considered a total of 4,500 valid evaluation texts. The experiment selects the first 4,000 sets of data among the 4,500 sets of data as training samples, while the remaining 500 sets were used as experimental test data. Furthermore, the corresponding evaluation target is used as the expected output value. The teaching quality evaluation error was set to 0.0001. We used the MATLAB_7.0 tool to write the program and implement the proposed algorithms. Similarly, we also carried out genetic algorithm to improve the training process of the convolutional neural network. Three evaluation metrics are used to compare the outcomes of various methods, i.e., (1) training time; (2) mean square error; and (3) goodness of

Table 1: The quality evaluation index system of mathematics teaching model reform.

First-level evaluation index	Secondary evaluation index	Index code
Teacher quality	Clear educational goals	X1
	Solid professional knowledge	X2
	The level of teaching explanation	X3
Teaching attitude	Counseling and answering questions patiently and positively	X4
	The lectures are conscientious and contagious	X5
	Rigorous attitude and strive for perfection	X6
Teaching content	Conceptual theory is accurate	X7
	Full of content and focus on ability	X8
	Connect with reality and focus on practice	X9
	Depth and breadth of expertise	X10
Teaching method	Good at inspiring and guiding thoughts	X11
	Various methods and appropriate use	X12
	Pay attention to individuality and teach students in accordance with their aptitude	X13
	Focus on stimulating innovation	X14
Teaching effect	Self-study ability and interest in learning	X15
	Basic knowledge understanding	X16
	Analyze and solve problems	X17
	Comprehensive quality and innovation ability	X18

Table 2: Evaluation result grade.

Grade	Score range
Excellent	[90, 100]
Good	[80, 89]
Medium	[70, 79]
Timely	[60, 69]
Failed	[0, 59]

fitness function [16]. Note that these evaluation metrics are most frequently used in the context of evolutionary optimization methods [17]. The experiments are performed on a Core i-7 CPU machine having 16 GB of memory and a GPU unit.

4.2. Improved Training Results of Convolutional Neural Networks Based on Genetic Algorithms. After the construction of the convolutional neural network structure is completed, we trained the network so that it can evaluate the quality index of mathematics teaching in colleges and universities. The training samples and the evaluation indicators corresponding to the samples need to be prepared in advance. According to the obtained indicators, this network model training is carried out using the experimental parameters as described earlier. The training results of the convolutional neural network, in terms of mean square error and number of training times, are shown in Figure 3.

According to Figure 3, the method suggested in this paper (the improve genetic algorithm) regards the modified linear unit as the running function in the entire neuron. Therefore, after 10 trainings periods, the accuracy requirement of 0.01 can be achieved. Similarly, the accuracy requirement of 0.001 can be completed after 20 training periods and the accuracy of 0.0001 can be completed after 50 training periods, respectively.

4.3. Comparison of the Evaluation Outcomes. The method suggested in this paper was compared with the methods proposed in the literature [4, 5]. The experimental parameters were kept the same during the comparison of the quality evaluation training outcomes of college mathematics teaching mode reform, and the results are shown in Table 3. Two evaluation metrics, i.e., the training time and goodness of fitness function, were used to evaluate the performance of various approaches and algorithms. The training times denote how many times the experiments were run. We considered variations in this metric with a repeated increase of 50. Overall, these values ranged from 50 to 500 to denote 10 iterations. Note that, in Table 3, error means mean square error. All other parameters along with machine specification were kept the same to ensure the accuracy of the outcomes.

From the evaluation and comparison of the 500-sample data in Table 3, the maximum error of the evaluation result of the method in this paper is 0.04, which is less than the evaluation error of the literature methods, because the literature methods do not use the gradient descent backpropagation method and cannot update the weights in real time. The training process is still using the previous weights. From our experimentation, this can be concluded that there is a large error in the teaching quality evaluation method. Therefore, the evaluation results obtained by the method suggested in this paper are very close to the real evaluation outcomes.

To further verify the effectiveness of the quality evaluation method of the reform of college mathematics teaching model based on the improvement of classical genetic algorithm, the analysis is carried out from the angle of goodness-of-fit function. The larger the result of the goodness of fit is, the closer the evaluation index result is to the real result. The experiment still chooses the literature methods as the control group of the proposed method. The change of the goodness of fitness function curve is shown in Figure 4.

Step 1: let the initial feasible solution and weight be randomly generated, then the initial feasible solution is $X_1, \ldots, X_L$; there are L in total, the weight is $w_1, \ldots, w_K$, and the number is K, where the value range of w_i is [0, 1] and satisfies $\sum_{i=1}^{K} w_i = 1$. Through the evaluation of the single optimization goal f_i and the comprehensive goal $F = \sum_{i=1}^{K} w_i f_i$, the initial temperature t_0 is clarified. Based on the comprehensive goal $F = \sum_{i=1}^{K} w_i f_i$, it is clear that the optimal solution $X*$ is reached, and after it is regarded as the current solution X, it meets $k = 0$.
Step 2: based on the neighborhood function, generate a new solution X' according to the current solution X and terminate when the solution is feasible to complete the evaluation of each optimization objective and comprehensive objective.
Step 3: if there is $F_{X'} < F_X$, then replace the current solution X with the new solution X' and then the current solution at this time becomes X', and if $F_{X'} < F_{X*}$, then replace the optimal solution $X*$ with the new solution X'; on the contrary, if there is $\exp[F_X - F_{X'}/t_k] > \text{random}(0, 1)$, then replace the current solution X with the new solution X'. If not, keep the current solution X.
Step 4: the current temperature sampling criterion meets the state implementation judgment. If it meets the sampling criterion, proceed to the next process; otherwise, return to the second step.
Step 5: implement temperature reduction treatment. There are $t_{k+1} = \lambda t_k$ and $k = k + 1$.
Step 6: if the algorithm termination condition is reached, the search stops and $X*$ is output; otherwise, it returns to the second step.

Algorithm 3: The improved genetic algorithm.

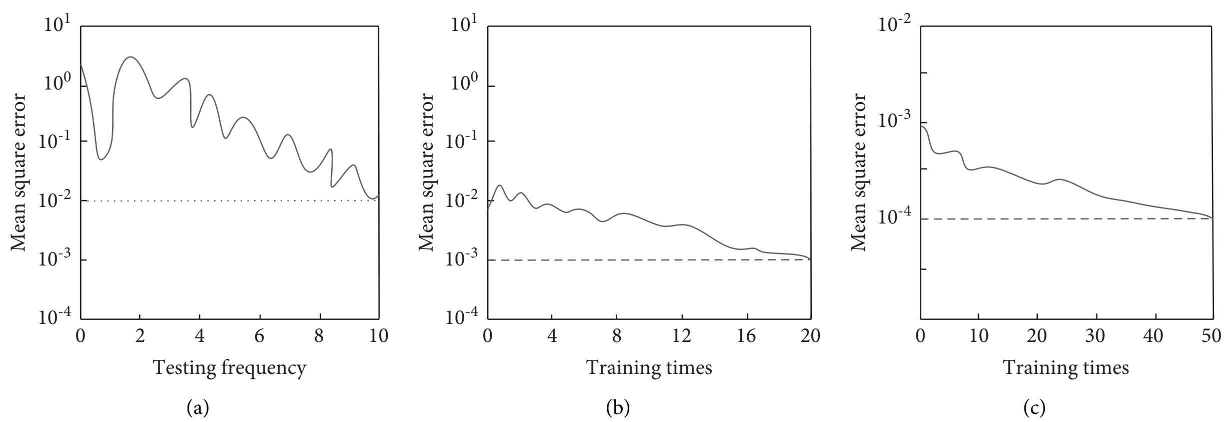

Figure 3: Convolutional neural network training error (error situation when the evaluation error is 0.01 (a), 0.001 (b), and 0.0001 (c)).

Table 3: Comparison of teaching quality evaluation results.

Training times	Method of this article		Literature [4] method		Literature [5] method		Actual value
	The assessed value	Error	The assessed value	Error	The assessed value	Error	
50	7.49	0.01	7.58	0.08	7.43	0.07	7.5
100	6.87	0.03	6.95	0.05	6.96	0.06	6.9
150	7.12	0.02	7.05	0.05	7.19	0.09	7.1
200	7.32	0.02	7.37	0.07	7.24	0.06	7.3
250	8.14	0.04	8.02	0.08	8.03	0.07	8.1
300	8.49	0.01	8.44	0.06	8.59	0.09	8.5
350	6.38	0.02	6.3	0.10	6.32	0.08	6.4
400	5.86	0.04	5.82	0.08	5.81	0.09	5.9
450	7.61	0.01	7.5	0.10	7.7	0.10	7.6
500	9.32	0.02	9.39	0.09	9.35	0.05	9.3

It can be clearly observed from Figure 4 that the goodness-of-fit curve obtained by the method proposed in this paper is higher than the curve of goodness of fit obtained by the literature methods. This is because the quality evaluation method of college mathematics teaching model reform based on genetic algorithm is almost subjective. Evaluation removal makes the evaluation result comprehensive; the genetic algorithm improves the convolutional neural network and uses the gradient descent back-propagation method, which can calculate the suitable gradient of the training sample in each iteration. This reduces the error of the actual teaching quality evaluation outcomes. Therefore, the results of the method suggested in this paper in terms of teaching quality evaluation are excellent.

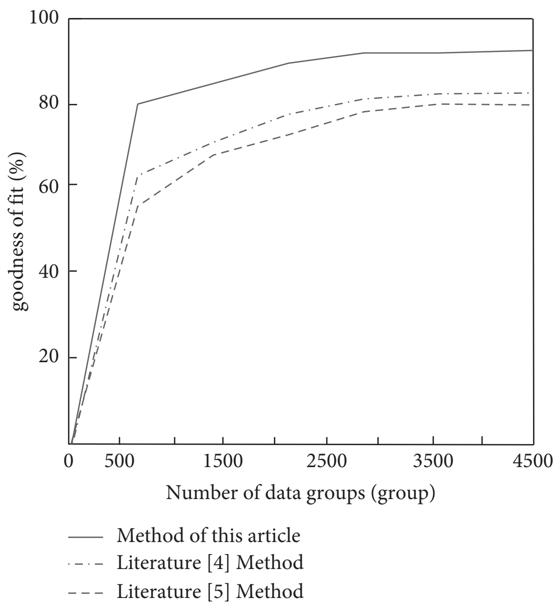

Figure 4: Comparison results of goodness of fit.

5. Conclusions and Future Work

With the continuous deepening and development of the college education reform and the increasing demand for applied talents in the society, at present, colleges and universities are facing huge difficulties and challenges in the training mechanism of mathematics talents. With the continuous development and progress of the times, how to effectively reform and innovate college mathematics is a difficult problem that needs to be solved effectively. Teaching quality evaluation is a very complex and fuzzy nonlinear process. In this process, multiple factors and variables are involved. Therefore, the establishment of mathematical models is more complicated, and traditional teaching quality evaluation methods are no longer fully competent to solve the issue. Only by applying the correct intelligent optimization algorithms to a reasonable teaching quality evaluation system can result in a scientific and reliable teaching quality evaluation model. In this paper, we proposed a method to evaluate the quality of college mathematics teaching mode reform based on an improved genetic algorithm.

Compared with traditional genetic algorithm, the simulated annealing algorithm has improved the diversity of new generations, and the performance of optimized neural network has been significantly improved. The improvement of mutation probability enhances the ability and speed of genetic algorithm to search for the global optimal solution, and the teaching quality evaluation model has more efficient convergence efficiency and more accurate prediction accuracy. The experimental results showed that the training error of the convolutional network of the proposed method is very small, the accuracy of the teaching quality evaluation outcomes is higher, and the goodness of fitness function value is better than other closest rivals. It can reduce the error of the actual teaching quality evaluation outcomes and can obtain a more accurate university mathematics teaching model reform quality assessment result. In the future, we will evaluate the model using other evolutionary algorithms including the well-known particle swarm optimization (PSO) and its various variants.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that he has no conflicts of interest.

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Research Article

Psychological Stress Detection and Early Warning System Based on Wireless Network Transmission

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To improve the accuracy of stress detection and stress warning errors, this paper designed a new psychological stress detection and warning system based on wireless network transmission. To achieve this objective, we established a real-time setup. The hardware of the system is composed of pulse acquisition module, signal low-pass filtering and amplification module, real-time clock module, wireless network transmission module, and power supply module, respectively. Based on the aforementioned hardware platform, the system software is designed, mainly through the construction of pulse signal noise and the use of wavelet denoising threshold for sensing wavelet packet inverse transformation, to get the reconstructed signal. The peak point of the reconstructed signal is determined, and the value of pulse signal is extracted. According to the characteristic value's extraction results, the degree of psychological stress is quantified using the psychological stress index (PSI). When the PSI exceeds a predefined threshold, it indicates an early warning of psychological stress. The experimental results show that the psychological stress detection of our system is consistent with the expert evaluation results, the warning time is short, and the practical application effect is good.

1. Introduction

Psychological stress is an important factor affecting human health. It is composed of multiple components such as cognition, psychology, and behavior and is a complex response mode, which is manifested as a person's physical and psychological tension when facing difficult requirements or environment [1]. According to research findings, a certain degree of psychological pressure (benign pressure) can stimulate people's initiative and improve productivity, but excessive psychological pressure will bring a series of problems. Under excessive psychological pressure, people's decision-making perception ability is affected, which damages productivity [2]. Long-term psychological pressure causes diseases like cerebrovascular disease, cardiovascular disease, and immune deficiency along with mental illness such as depression and anxiety. Hence, a person's life and health are impacted, which makes him/her unable to withstand the psychological pressure caused by social security incidents [3]. Therefore, the diagnosis and research of psychological stress are of great significance to human health and social stability [4].

Psychological stress is an important factor affecting human health. When psychological stress exceeds the bearing ability of an individual, it leads to a high incidence of diseases and affects human health [5]. In real life, psychological pressure has increasingly become a major factor affecting people's physical and mental health and quality of life [6]. For effective detection and warning of psychological stress, quantitative measurement is required. However, subjective emotions and outsiders' experience cannot accurately evaluate a person's psychological stress, and the judgment must be assisted by the body's signs, so as to improve the effect of psychological stress detection and warning [7].

Therefore, according to the above analysis, this paper designed a psychological stress detection and early warning system based on wireless network transmission. The major contributions of this work are as follows:

(1) This paper provides real-time measurement for psychological stress by designing an early warning system. The hardware design platform is discussed in

detail and its distinguishing features are highlighted. To this end, this paper discusses its own unique wireless network transmission module.

(2) Pulse signal's noise is examined and a low-pass filter is used to protect the voiceless component in the speech signal. The low-pass filters smooth the TEO coefficient by obtaining a mask for a particular subband. Using the coefficient and masking, the inverse wavelet packet transform of perception is carried out to obtain the reconstructed signal.

The rest of this paper is organized as follows. In Section 2, the psychological stress detection and early warning system is examined in detail. In Section 3, the experimental environment and results are discussed. Finally, the paper is concluded in Section 4.

2. Psychological Stress Detection and Early Warning System

In this section, first we discuss the design of our system hardware platform that was required to conduct this study. Next, we discuss the system software design and proposed methodology of this paper.

2.1. System Hardware Design. The hardware of psychological stress detection and early warning system mainly includes pulse acquisition module, signal low-pass filtering and amplification module, real-time clock module, wireless network transmission module, and power supply module, respectively.

2.1.1. Pulse Acquisition Module. To realize accurate collection of pulse signal, SC0073B micro-dynamic pulse micropressure sensor is used [8]. It is a miniaturized piezoelectric sensor, which uses the electric film as the energy exchange material. The pulse pulsates and presses the film of the pulse sensor to produce the output of charge. The sensor has the physical characteristics of simple operation: its small volume and lightweight and low-cost features. Its advantages are high sensitivity coefficient, strong resistance to overload and shock waves, and good resistance to external interference. The application circuit design of SC0073B pulse sensor is simple. It only needs to be connected in series with a 10 K resistor. The circuit structure of pulse acquisition module is shown in Figure 1.

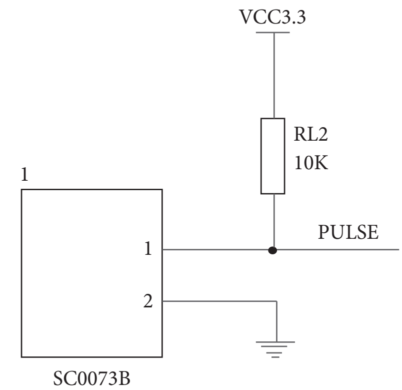

Figure 1: Circuitry of the pulse acquisition module.

2.1.2. Signal Low-Pass Filtering and Amplification Module. Because the SC0073 B pulse sensor is very sensitive, the external high-frequency disturbance greatly interferes with the pulse signal. Hence, this paper adds a low-pass filter circuit to the hardware system [9]. The additional high-frequency disturbance signals can be filtered out by effective RC combination. The pulse signal frequency range is from 0.8 Hz to 10 Hz, so the upper limit cutoff frequency of the low-pass filter is 25 Hz. Thus, the following equation exists:

$$f = \frac{1}{2\pi RC}. \tag{1}$$

It can be observed that the upper limit cutoff frequency of RC low-pass filter is related to the values of R and C. In (1), $f = 25\,Hz$ and C is fixed at $0.1uf$; thus,

$$R = \frac{1}{2\pi Cf}. \tag{2}$$

If $R \approx 637\,\Omega$ and the nominal value of the nearest resistance is 620, then the upper limit cutoff frequency is 25.6 Hz, which meets the design requirements. The low-pass filtering circuit is shown in Figure 2.

The output signal amplitude of SC0073B pulse sensor is nearly 200 mV. In order to improve the AD sampling accuracy of embedded processor, this paper adopts AD623 high-precision differential amplifier to amplify and process the pulse signal [10].

The AD623 has a high input impedance, a low output impedance, and a high common mode rejection ratio and can achieve small signal amplification from 1 to 1000 times via an external gain resistor. AD623 can be dual power supply or single power supply and has a zero adjustment circuit interface through the external potentiometer adjustment. These features realize the balance output of zero adjustment. The system in this paper adopts 3.3 V embedded processor, so the input voltage range of AD interface is 0 to 3.3 V. Therefore, in this paper, the output signal of the pulse sensor was amplified by 10 times [11], and the gain resistance of AD623 was calculated using

$$V_o = \left[1 + \frac{100K\Omega}{R_G}\right]V_i. \tag{3}$$

Here, $R_G \approx 11K$. The AD623 amplifier circuit is shown in Figure 3.

In Figure 3, RL1, RL6, RL7, and RL4 constitute the balance bridge circuit, whereas CL1, CL2, and CL3 constitute the input filter circuit.

2.1.3. Real-Time Clock Module. The psychological stress detection and early warning system, designed in this paper, need to record the real pulse sampling interval. For this

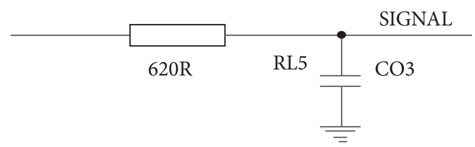

Figure 2: Circuitry of low-pass filtering.

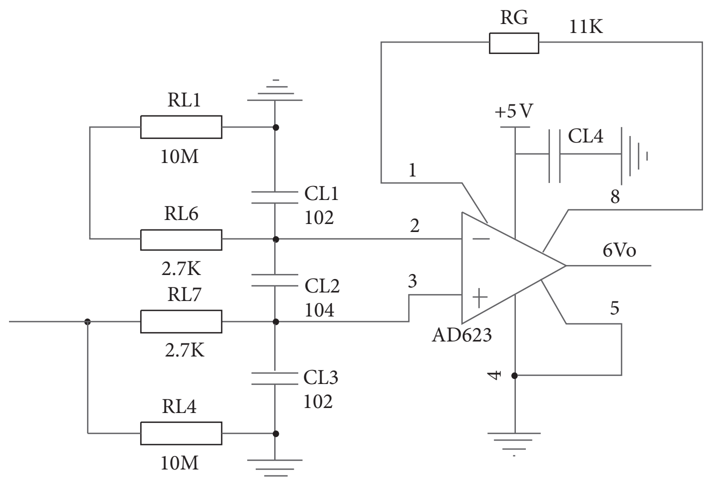

Figure 3: Enlarged circuit diagram of AD623.

purpose, the real-time clock module needs to be designed [12]. The real-time clock chip model is RX6110, which has a built-in oscillator and integrated calendar function, and uses I2C bus to communicate with MCU. The circuit configuration is relatively simple, as shown in Figure 4.

It should be noted that the clock chip needs at least 40 ms startup time when it is powered on, and registers in the chip cannot be read or written before the startup is completed.

2.1.4. Wireless Transmission Module. The collected pulse signal eventually needs to be uploaded to a PC for processing. This system uses CP2102 chip to realize UART/USB conversion. The circuitry of wireless network transmission module is shown in Figure 5.

The serial communication rate is set at 115200 bps, there is no parity check, and one stop bit is used. In addition to the communication function, CP2102 also integrates 3 V LDO, which can stabilize the input voltage of 5 V to 3 V and directly output to the processor.

2.1.5. Power Supply Module. This system is powered by USB and lithium rechargeable battery, and the circuit is shown in Figure 6.

When the power supply is connected to USB, it is powered by USB interface that charges the rechargeable battery. In this case, the charging current is slightly less than 1 A. When the USB interface is disconnected, it is automatically powered by a rechargeable battery. The processor can easily identify the USB connection status and charging status and can sense the charging battery voltage. In practical tests, the 2000 mAh battery provides the system with at least 50 hours of continuous operation on a full charge.

2.2. System Software Design. Pulse is an important physiological signal of human body, which is well known and has rich clinical experience. The continuous periodic contraction and diastole of the heart cause blood to flow from the aortic root along the arterial system, and vascular pressure is generated during the blood flow. The response of pressure wave generated by the change of vascular pressure and blood flow on the body surface can be called pulse [13]. Under normal circumstances, the pulse signal is continuous, close to cyclical deterministic signal. The pulse of different individuals in different states is not identical. Under normal circumstances, a person's pulse frequency is 60 to 100 times/min. The pulse signal is, in fact, not certain, so the pulse signal is not stable and changes periodically. It changes with the changes of various physiological and psychological factors of the human body and the external environment, and the waveform obtained through instruments and equipment will also change accordingly [14]. Pulse signals have the following characteristics:

(i) It is vulnerable to external interference and has the characteristics of small amplitude. Because pulse signals originate from the surface of the human body and ranges from 10 V to 100 V, they are highly susceptible to interference by EMG signals, electronic devices, and mental stress.

(ii) Pulse signal beats about 1 to 10 times per second, which is a typical low-frequency signal. The pulse frequency of normal healthy human body is 1–5 Hz, and the pulse frequency may exceed this range in some healthy cases [15]. In general, the distribution of pulse frequency will be less than 1 Hz or more than 5 Hz when human lesions occur.

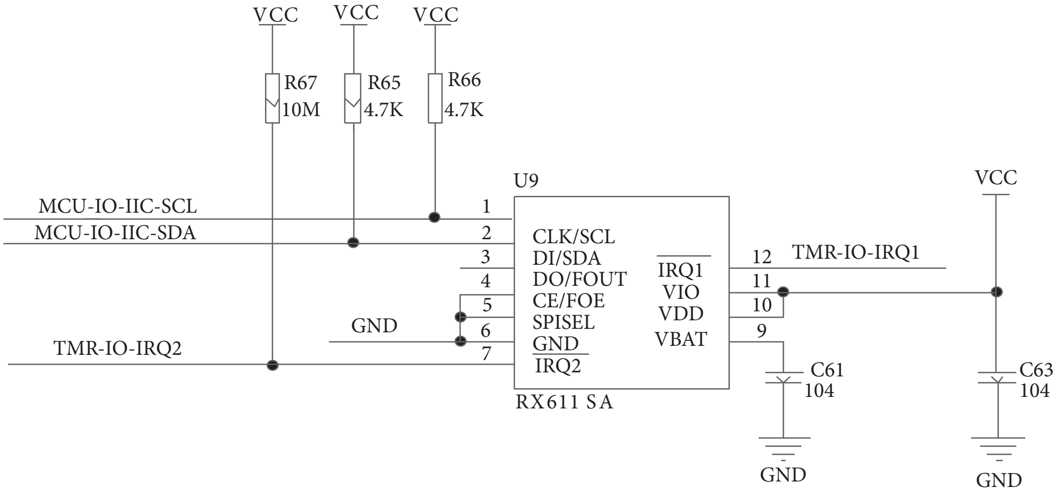

Figure 4: Real-time clock circuitry.

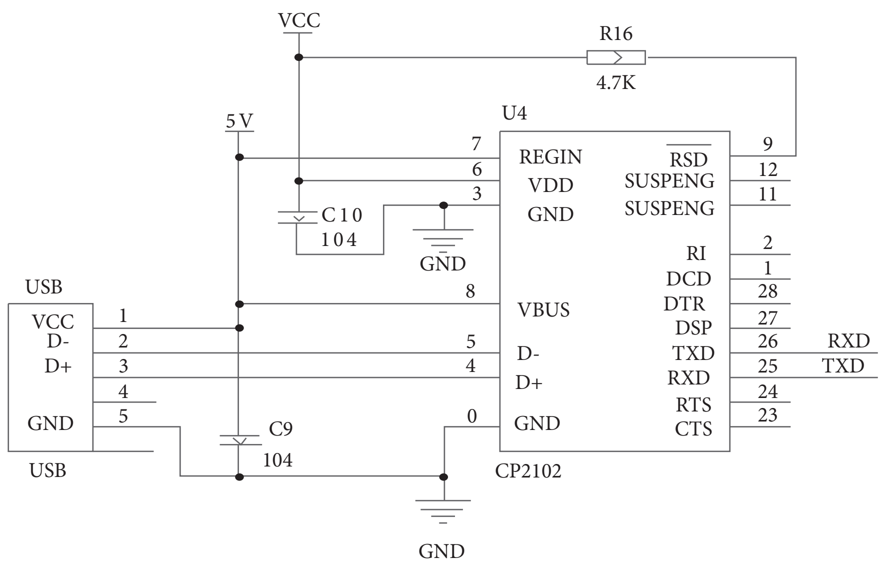

Figure 5: Wireless network transmission module circuitry.

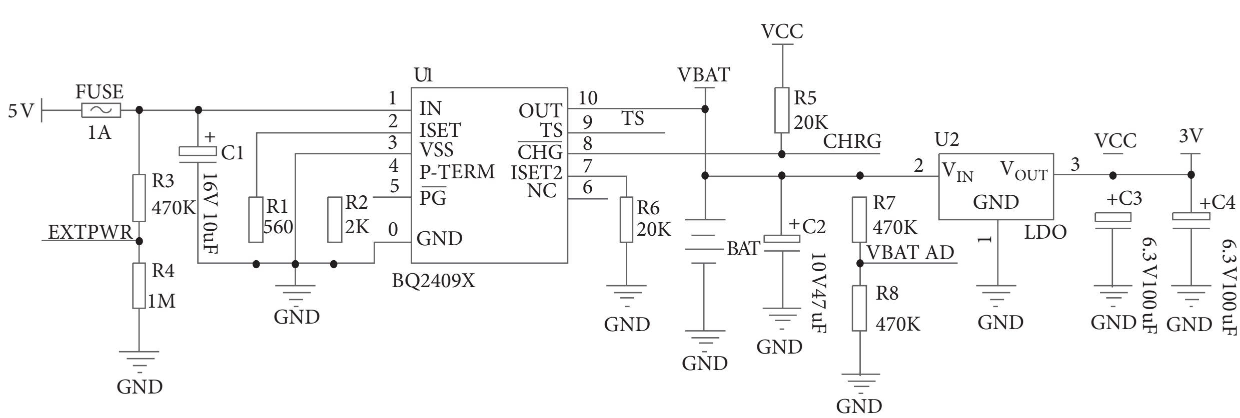

Figure 6: Power supply circuitry.

(iii) It has the characteristics of volatility and instability and changes with the changes of various physiological and psychological factors of the human body and the external environment, presenting different pulse conditions. Because of the complexity and uncertainty of pulse detection, it is nearly impossible to directly analyze and summarize its characteristics from pulse signals. Hence, it is impossible to determine whether some signals are meaningful or not.

In this paper, if the signal is denoted by $s(n)$, then the pulse signal's noise model in the actual environment can be simplified using

$$s(n) = f(n) + \sigma \cdot e(n), \tag{4}$$

where $f(n)$ is pure signal, $e(n)$ is noise, and σ is the noise intensity. In simple case, $e(n)$ is Gaussian white noise and $\sigma = 1$.

The wavelet's packet structure is used to decompose the perceptual wavelet packet of noisy speech signal, and multiple wavelet subbands are obtained using

$$w_j(k) = \mathrm{PWPD}\{x(n)\}, \tag{5}$$

where $w_j(k)$ represents the wavelet coefficient in the subband $j = (1, 2, \ldots, n)$ and k is the sequence number of the wavelet coefficient.

The improved Teager energy operator (TEO) coefficient is calculated by using (6), which is described as follows:

$$t_j(k) = E'\left[w_j(k)\right]. \tag{6}$$

Among them,

$$E_n = \frac{\left(3x_n^2 - 4x_{n-1}x_{n+1} + x_{n-2}x_{n+2}\right)}{3}. \tag{7}$$

A second-order low-pass IIR filter is used to smooth the TEO coefficients, and a mask $M_j(k)$ is obtained. Through low-pass filtering operation, the voiceless component in the speech signal can be well protected using

$$M_j(k) = t_j(k) \cdot h_j(k), \tag{8}$$

where $h_j(k)$ represents the smoothing coefficient.

The compensation value S_j is found from the distribution function using

$$S_j = \text{abscissa}\left[\max\left(H\left(M_j(k)\right)\right)\right]. \tag{9}$$

A new mask is obtained by processing the above results. The compensation value is the maximum distribution of the mask values. The results are as follows:

$$M'_j(k) = \left[\frac{M_j(k) - S_j}{\max\left(M_j(k) - S_j\right)}\right]^{1/8}. \tag{10}$$

Next, divide the subbands into different parts and calculate the variance of each part. The result is as follows:

$$w'_{j,m}(k_m) = \text{Split}\left[w_j(k)\right], \tag{11}$$

where $w'_{j,m}(k_m)$ is the wavelet coefficient of the m^{th} part of the j^{th} subband and k_m is the sequence number of the wavelet coefficient after frame splitting. The proportionality coefficient is defined as

$$\beta_{j,m} \frac{\min\left[\mathrm{var}\left(w'_{j,m}(k_m)\right)\right]}{\mathrm{var}\left(w_{j,m}{}'(k_m)\right)}. \tag{12}$$

For a given subband j, its adaptive threshold is defined as

$$\lambda'_j(k) = \beta_{j,m} \cdot \lambda_j\left(1 - M'_j(k)\right), \tag{13}$$

where λ_j represents the fixed thresholds of different subbands and is calculated using

$$\lambda_j = \sigma_j \sqrt{2 \log\left(N \log_2 N\right)}. \tag{14}$$

In (14), σ_j represents the noise intensity of subband j and N represents the number of subbands.

In this paper, adaptive threshold is used to conduct soft threshold processing for each subband coefficient, and its processing is highlighted using (13).

$$\widehat{w}_j(k) = \begin{cases} 0, & \left|w_j(k)\right| \le \lambda_a, \\ \mathrm{sgn}\left(w_j(k)\right)\left(\left|w_j(k)\right| - \lambda_a\right), & \left|w_j(k)\right| > \lambda_a, \end{cases} \tag{15}$$

where λ_a represents the wavelet denoising threshold and is calculated using

$$\lambda_a = \begin{cases} \lambda'_j, & S_j \le 0.35 \max\left(M_j(k)\right), \\ \lambda_j, & S_j > 0.35 \max\left(M_j(k)\right). \end{cases} \tag{16}$$

According to the processed coefficients, the inverse wavelet packet transform of perception is carried out to obtain the reconstructed signal:

$$\widehat{x}(n) = \mathrm{PWPD}^{-1}\left\{\widehat{w}_j(k)\right\}. \tag{17}$$

According to the sample data, the basic analysis found that although the shape of each pulse signal waveform is not exactly the same, but each pulse waveform of the distribution and morphological characteristics of peaks and troughs are almost constant. Moreover, the pulse signal acquisition and pressure curve's turning point positioning is the pulse signal eigenvalue extraction. At the same time, there are several turning points in a pulse signal, which shows that the extreme value point of the basic characteristics of pulse signal waveform is stable. The extraction algorithm based on the peak of the pulse signal was analyzed along with the positioning of the pulse of a few key extremum points. The analysis of extreme value point of properties ensures to get the maximum and minimum values. Thus, a pulse waveform is quantitatively calculated and the physiological information contained in the value is analyzed. Figure 7 is the basic flow chart of the complete waveform detected by the extreme point of the pulse signal based on the peak value.

The basic description of the complete waveform of pulse signal's extremum point detection as shown in Figure 7 is as

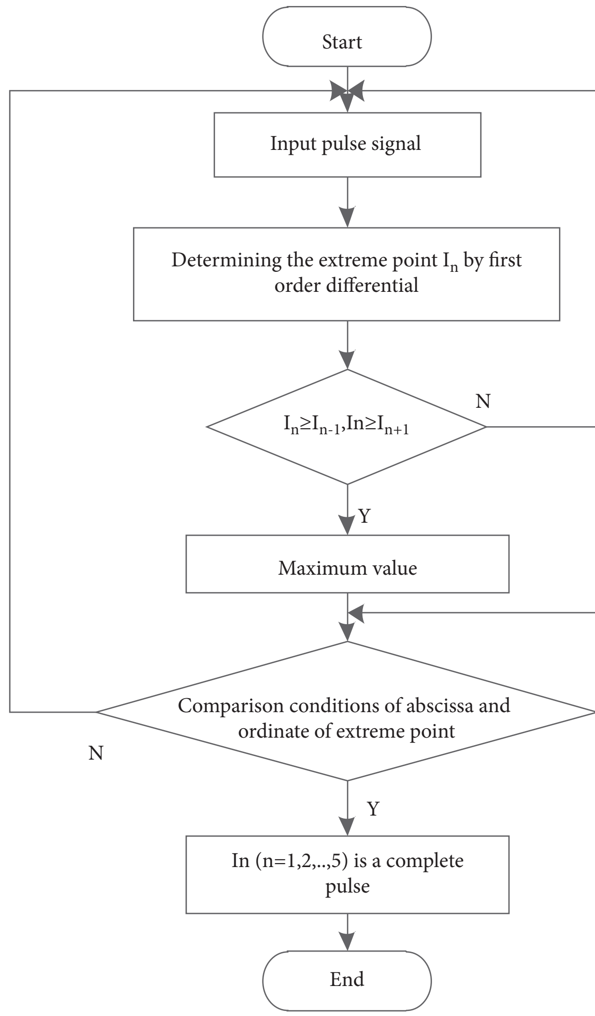

Figure 7: Flowchart for waveform detection.

follows: after the pulse signal is filtered, it enters the detection program, the extremum point of pulse signal is determined through first-order differential, and the amplitude of several adjacent extremum points is compared and determined.

For the first five adjacent extreme points I_1, I_2, I_3, I_4, and I_5 if

(i) I_1, I_3, I_5 are local minima, and $Y_{11} < Y_{13}$, $Y_{11} < Y_{13}$, (Y_i is the y-coordinate of I)

(ii) I_2 and I_4 are local maxima, and $Y_{12} > Y_{14}$

(iii) $Y_{12} > Y_{11}$ and $Y_{12} > Y_{13}$

(iv) $Y_{14} > Y_{13}$ and $Y_{14} > Y_{15}$

(v) $X_{15} - X_{14} > X_{12} - X_{11}$ (X_i is the abscissa of point I)

The above statements show that I_1, I_2, I_3, I_4, and I_5 locate a complete pulse. If these five requirements/statements are not met, the first point I_1 is discarded and the sixth extreme point I_6 is added. The five new extreme point sequences I_1, I_2, I_3, I_4, and I_5 are taken as the new sequence to judge whether the above conditions are met by moving the panes one by one to be determined. If all of the above five points are met, then they are determined to locate a complete pulse. In the next judgment, these five points should be discarded and the next five extreme points should be added to repeat the above judgment. If successful, Step 5 uses units of extreme point to judge the feature points.

According to the determination of the peak point, after extracting the characteristic value and obtaining the complete pulse, we can accurately calculate the subamplitude, heartbeat interval, the amplitude of the repeat pulse, the first and second peak interval, etc., i.e., the number of complete pulse, pulse amplitude (PPGA), and heartbeat interval (HBI).

The original data of pulse amplitude and state interval need to be normalized through normalization calculation. Linear normalization algorithm is used to normalize the data from 0 to 1 using

$$\text{norm} = \frac{(\text{data} - \min)}{(\max - \min)}. \tag{18}$$

Psychological stress index is widely used in the operation process to monitor the pain of patients during the operation. The more the surgical pressure index value approaches 100,

Table 1: Experimental environment.

Experimental environment	Configuration	Parameter
Hardware environment	CPU	Intel(R)Core(TM)i5-9400
	Frequency	2.90 GHz
	RAM	16.0 GB
Software environment	Operating system	Windows 10
	Version	18362.1082 pro
	Digits	64 bit
	Analog software language	APDL

the higher the stress level of the patient is. The more the index value approaches 0, the lower the stress level of the patient is. In order to effectively carry out the psychological stress test, the psychological stress index (PSI) is proposed to quantify the degree of psychological stress. The equation of the psychological stress index is as follows:

$$\mathrm{PSI} = 100 \times (1 - J \times \mathrm{PPGAnorm} - (1 - J) \times \mathrm{HBInorm}). \tag{19}$$

According to the above analysis, a threshold value is set. When the PSI $\geq T$, the subject is considered to be under too much psychological pressure. At this time, the system should be used for early warning, so as to further reduce people's psychological pressure and improve people's mental health level through relevant intervention means.

3. Experimental Setting and Result Analysis

In this section, the experimental setup is provided in Section 3.1. The comprehensive analysis and discussion of various experimental results are discussed in Section 3.2.

3.1. Experimental Settings. In order to verify the practical application of the psychological stress detection and early warning system based on wireless network transmission, experimental analysis is needed. For this purpose, an experimental environment needs to be setup, as shown in Table 1.

Pulse signal is collected according to the above experimental settings, and the specific environment is shown in Figure 8.

To measure the effectiveness of stress detection and warning system, it is necessary to set up the experimental paradigm of inducing psychological stress. Research approaches of psychological pressure identification have special circumstances, special groups, and experimental excitation. The expectations of crowd recognition add to the natural pressure, although the authenticity and validity are better. Stress tasks in experimental environment can stimulate certain psychological stress and cause changes in physiological signals. Most of these tasks stimulate psychological stress through experiments. These tasks are mainly used in public speaking and language interaction, cognition, emotional elicitation, noise exposure tasks, etc.

Proactive tasks require the subjects to make timely cognitive responses, such as public speaking and mental arithmetic. Social evaluation factors generally include permanent record of personal performance through audio tapes or video cameras. At least one member of the audience takes part in the test subject's task. In this study, different subjects were compared. Since proactive task and social evaluation are more capable of causing significant physiological responses, this study adopted proactive stress task combined with speech and cognitive task, which is described as follows:

(i) Proactive task: the subject is required to make a speech and discussion on stage in nonnative English
(ii) There is a time limit for the speech process, which is set at 10 minutes
(iii) Give a speech to two experts and engage in discussion with them
(iv) Let two subjects give a speech in adjacent places at the same time, and the subjects know the process

3.2. Analysis of Experimental Results. In order to verify the effectiveness of the system designed in this paper, the psychological stress of 1000 subjects was tested, and the test results were compared with the expert results. Among them, the subjects' mental health test results were scored by several psychological experts to take the average of the final results. The comparison results for the first 20 subjects are shown in Table 2.

The analysis of the data in Table 2 shows that the psychological stress test results obtained in this paper are basically consistent with the expert evaluation results. The remaining 980 subjects were tested, and the results were basically consistent with the expert evaluation results. These results can realize the psychological pressure and high precision detection. According to the above results, in the 1000 subjects, more than half of the subjects' psychological stress exceeds the threshold value, so the psychological stress warning time will be tested. Since the early warning time of psychological stress is also one of the important indicators to verify the psychological stress detection and early warning system, the subjects whose psychological stress threshold exceeds the threshold are selected for the psychological stress early warning time test, and the results are shown in Figure 9.

According to the data in Figure 9, the warning time of the system designed in this paper varies between 0.11 s and 0.64 s in the process of warning for 500 subjects whose psychological stress exceeds the threshold. This indicates

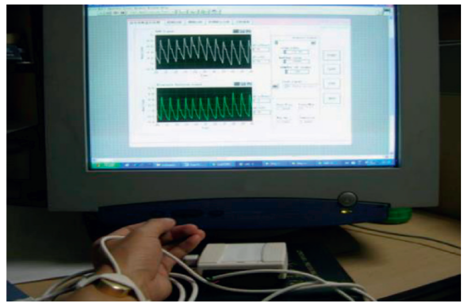

Figure 8: Experimental environment for pulse signal acquisition.

Table 2: Comparison of psychological stress test results.

Subject number	Expert rating	The system test results presented in this paper
1	56	57
2	23	23
3	35	36
4	86	85
5	75	76
6	21	22
7	28	28
8	41	40
9	36	36
10	66	67
11	35	34
12	87	88
13	74	74
14	83	85
15	56	56
16	42	41
17	33	33
18	80	78
19	74	71
20	46	46

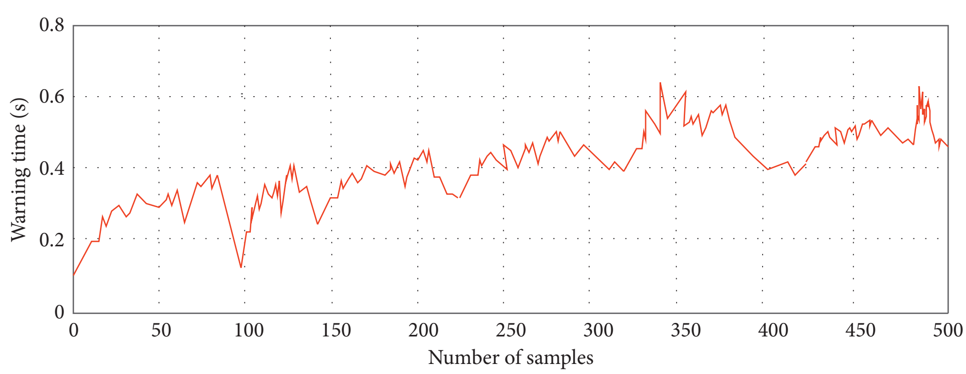

Figure 9: Psychological stress warning time test results.

that the warning time of this system for psychological stress is short and the warning efficiency is high, which can be further promoted in practice.

4. Conclusion

In modern society, people are exposed to all kinds of stress. They often need to work under pressure that affects their life, interpersonal relationship, and various other aspects. Persistent stress can bring mental and physical obstacles and defects, so the prevention, diagnosis, and treatment of psychological stress have received extensive attention from all walks of life, especially in the medical field. This paper designed psychological stress detection and early warning system based on wireless network transmission and proposed system development through the system hardware and software design. Experimental results show that psychological stress test results are almost consistent with expert evaluation results, and the warning time is shorter. Furthermore, the proposed system has high psychological pressure detection accuracy and low detection time. In practice, it can further promote and lay a solid foundation for modern people to alleviate psychological pressure.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

Acknowledgments

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Research Article

College Students' Self-Acceptance: A Paint Therapy Group Counseling Intervention

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This research highlights the effect of paint therapy group counseling on college students' achievement in the field of education. For this purpose, we have used a quasiexperimental design with pretest/posttest of control group and experimental group. The sample used in our experiment consists of 18 students at a university in Guangdong Province. Participants were randomly assigned to two groups, i.e., experimental group and control group, and completed pretest and posttest measures of self-acceptance and self-evaluation over 2 months. The difference between the two groups before and after the intervention was determined using an independent-samples t-test. We have also used a paired-sample t-test to compare the effects of the intervention on the experimental achievement scores of the groups. The results showed that the self-acceptance score in the experimental group's posttest was 40.78 ± 6.91 ($t = 3.66$, $p < 0.01$), while the scores of self-acceptance factor and self-evaluation factor were 20.67 ± 4.12 ($t = 3.19$, $p < 0.05$) and 20.11 ± 3.59 ($t = 3.71$, $p < 0.01$), respectively. Besides, the two months, posttest follow-up showed that the self-acceptance score was 43.67 ± 4.64 ($t = 1.0$, $p < 0.05$), and the scores of self-acceptance factor and self-evaluation factor were 22.11 ± 2.85 ($t = 4.06$, $p < 0.01$) and 21.56 ± 2.65 ($t = 2.86$, $p < 0.05$), respectively.

1. Introduction

Self-acceptance is crucial during the shift from a child to an independent adult. Self-acceptance refers to the positive and negative characteristics individuals attribute to themselves [1]. Categorized as one of the many critical issues under Rational Emotive Behavior Therapy [2, 3], self-acceptance acknowledges "one is a complex, imperfect human being capable of making mistakes" [4]. To this end, individuals are encouraged to refrain from self-criticism of their body image, self-worth, and giving credence to other's people's negative judgments [4]. This perception of self is also integral to a person's self-evaluation, with young people undergoing varying levels of emotions that correlate with their feelings of self-worth. Negative self-evaluations, coupled with hormones, and stress (real or imagined) contribute to feelings such as depression and result in the breakdown in psychological health. Conversely, positive self-evaluation assists with goal setting, as well as motivational and performance improvement, and is closely annexed to self-knowledge and self-consciousness [5]. Accordingly, Albert Ellis argues self-evaluation's importance in the acceptance of self and others [6].

For young people, college is a period of adaptation with incremental development tasks toward self-identity [7] and adulthood [8]. Self-evaluation and self-acceptance contribute to students' psychological health and well-being and are important factors in their coping and emotional skills and social interactions [9]. Numerous studies have highlighted the adverse effects of poor self-concept among college students to include episodes of eating disorders, pregnancy, mental health issues, and high attrition [10]. To address these disorders, researchers have found that the self-acceptance levels of different groups such as male drug addicts [11], primary school students [12], juvenile offenders [13], and vocational school students [14] were positively affected by group counseling. Group counseling allows for multifaceted issues to be addressed in a single session [8]. Effective group counseling techniques include psychotherapies such as hypnotherapy [15], imagery dialogue [16], dance movement therapy [17], and sports games [18]. Paint or art therapy is another technique that has the unique advantage of incorporating relaxing and joyful activities while simultaneously reducing negative subconscious symptoms. Using an experimental-comparison research design, the authors in [19] conducted art therapy intervention using clay to demonstrate the positive effects on college students' anxiety levels over ten weeks. The authors in [9] sought feedback from 68 participants after their participation in 12 different art therapy groups. Most of the participants (98%) reported positive impacts on their psychological health. The efficacy of this treatment in self-acceptance among college students is an underresearched albeit burgeoning area in the discipline, with published studies indicating varying levels of success.

The aim of this study, therefore, is to explore the effects of a paint therapy group (PTG) counseling intervention on college students' self-acceptance level using an experimental pretest-posttest follow-up control group design. The study is conducted at a university in China and is significant for the sharing of expressions and emotions in a predominantly conservative society. The following hypothesis is proposed: group paint therapy counseling can improve college students' self-acceptance level. The main contributions of this work are as follows:

(1) The aim was to improve the self-acceptance level of college students by using paint therapy group counseling technique.
(2) The scores of self-acceptance factor and self-evaluation factor were improved.
(3) The self-acceptance questionnaire (SAQ) score, self-acceptance factor, and self-evaluation factor of the control group, during this work, had no significant difference when comparing pretest and posttest. Hence, this revealed that the PTG counseling intervention has a positive effect on the self-acceptance level of the subjects.
(4) Independent-samples *t*-test was conducted on the self-acceptance levels of the two groups but there was no statistically significant difference.

The rest of this paper is organized as follows: In Section 2, we explain material and methodology used for this work; in Section 3, we discuss our experimental work and its results; Section 4 presents discussion and limitation of our proposed scheme, and finally conclusion is presented in Section 5.

2. Material and Methodology Used

2.1. Paint Therapy (Art Therapy). Art is the item or cycle of purposely organizing things (frequently with representative importance) such that it affects and influences at least one of the faculties, feelings, and insight. It is anything but an assorted scope of human exercises, manifestations, and methods of articulation, including music, writing, film, photography, figure, and works of art. Meanwhile, the utilization of creative techniques to treat mental problems and upgrade emotional wellness is known as paint therapy (art therapy). Paint therapy is a strategy established in the possibility that imaginative articulation can cultivate mending and mental prosperity [20]. The advantages of paint therapy are listed as follows:

(1) Therapy should be centered on personal development, rehabilitation, psychotherapy, correction, adaption, and/or personality enhancement
(2) Integrate personal training in art and therapy with the understanding of theories of normal and abnormal behavior, graphic symbolic expression, and intervention strategies to respond to clients' strengths and needs
(3) Individual or group work with people of various ages in a collection of settings reduces the severity of depression or anxiety problems
(4) Assist customers who are suffering with illness, trauma, or loss
(5) Reduce work/school-related stress
(6) Interpersonal interactions should be improved
(7) Assist clients in increasing their self-awareness and self-esteem, improving their cognitive capacities, and/or encouraging creativity and personal growth
(8) Patient care services are provided

2.2. Group Counseling. Group counseling is a type of counseling in which a small number of people meet on a routine basis to talk about, interact with, and explore issues with one another and the leader of the group. Group therapy aims to provide a safe and comfortable environment in college for learners to sort out their problems and emotional concerns. Participants gain insight into their ideas and actions and offer advice and support to others. Other advantages of group counseling are listed as follows:

(1) Support is given and received
(2) Investigate potential solutions after gaining a better knowledge of the issues
(3) In a secure group context, practice interpersonal skills
(4) Discover more about how others perceive you
(5) Improve observation and feedback abilities
(6) Improve problem-solving abilities
(7) Enhance emotional expression
(8) Reduce social isolation
(9) Improve communication abilities

Depending on the mental health condition as well as the therapeutic procedure employed during the counseling, counseling can be classified into many forms.

- Cognitive behavioral groups: this type focuses on discovering and altering incorrect or distorted thought processes, emotional reactions, and behaviors
- Interpersonal groups: this type focuses on interpersonal relationships and social interactions, such as how much assistance you receive and how these relationships affect your mental health
- Psychoeducational groups: this type focuses on educating patients about their diseases and coping mechanisms, generally using cognitive behavior therapy (CBT) ideas
- Skills development groups: this type focuses on helping people with mental illnesses or physical disorders improve their social skills
- Support groups: people with a variety of mental health disorders, as well as their loved ones, can benefit from this form of treatment

2.3. Subjects. Eighteen participants were selected after undergoing a screening process. Volunteers were recruited through posters and texts on WeChat public accounts posted at Beijing Normal University Zhuhai, China, and comprised students from education, management, business, and Chinese colleges. 72% of the participants were females, with mean age of 19 ± 19 years. All participants came from urban families.

2.4. Procedure. The University Ethics Committee approved the research plan and all participants signed informed consents. Group leaders were teachers and student assistants of the university's counseling center and had received professional training in clinical psychology and group counseling. Participants were randomly divided into two groups: the experimental group ($n = 9$; 7 females and 2 males) and the control group ($n = 9$; 6 females and 3 males). The experimental group received eight weeks of paint therapy group counseling, while the control group received none.

Selection of research subjects underwent two stages. In the first stage, 78 participants were interviewed. Two aspects were addressed for inclusion: (1) participants' basic human condition (i.e., physical state, emotion, conflict, etc.) and willingness to participate in the self-acceptance group counseling and (2) introduction of the study objective and in-depth clarification in response to questions. In the second stage, after the interviews, six subjects who were diagnosed with a mental disorder and were receiving drug treatment were excluded. Remaining subjects were screened, and the self-acceptance level scores from the remaining subjects were measured and ranked from high to low. Subjects who scored in the top 27% were set as the high group and those who scored in the last 27% placed in the low group. Eighteen subjects were randomly selected from the low group, which were then randomly assigned to the experimental group as well as to the control group. Independent-samples t-test was conducted on the self-acceptance levels of the two groups but there was no statistically significant difference.

3. Methods

3.1. Measuring Instruments. In this research work, we have adopted [21] self-acceptance questionnaire (SAQ) which is a commonly used questionnaire in China. Our SAQ consists of 16 items divided into two subscales: self-acceptance and self-evaluation. Self-evaluation (SE) refers to the judgment and evaluation of one's own thoughts, expectations, behaviors, and personality characteristics, which is an important condition of self-regulation [22]. During our experiment, the eight self-acceptance items (1, 4, 7, 8, 11, 13, 14, and 16) were scored reversely on a 4-point Likert scale (1 = very opposite to, 4 = very similar). The higher the score is, the higher the degree of self-acceptance of the research object is and vice versa. Similarly, the eight self-evaluation items (2, 3, 5, 6, 9, 10, 12, and 15) were scored positively on a 4-point Likert scale (1 = very similar to, 4 = very opposite). From this, we concluded that the higher the score is, the higher the degree of self-acceptance of the research object is and vice versa.

Cronbach's alpha is a metric for determining the internal logic or reliability of a test or scale item. Cronbach's alpha is calculated by comparing the variance of all single-item scores to the total score for each observation. Cronbach's alpha for our proposed scheme can be seen by

$$\alpha = \frac{NP}{V + (N-1) \cdot P}, \tag{1}$$

where N is the total number of participants; P represents average covariance between participants-pairs; and V represents average variance.

Therefore, Cronbach's coefficient alpha for internal consistency of the self-acceptance factor and self-evaluation factor in our scheme were .93 and .91, respectively, while the correlation coefficient between the two factors was .37 ($p < 0.0001$), and the retest reliability of the questionnaire was .77, indicating a good validity [23].

3.2. Design of the Experiment. We used a quasiexperimental approach with collaborative learning as the instructional model and typical lecture technique groups, similar to [24]. Because of its resistance to frequent risks to validity and reliability, this is called experimental research design. Figure 1 illustrates a methodical framework for the design.

Due to the scope of the issue and the study hypotheses, we have chosen this design. Following a selection process, a total of eighteen volunteers were selected for the experiment. In addition, students from education, management, business, and Chinese universities were recruited using posters and texts put on WeChat public accounts at Beijing Normal University Zhuhai, China. The majority of the participants (72%) were females, with an average age of 19–19 years. The study has two groups: an experimental group of 9 students and a control group of 9 students.

We conducted an activity in which we divided a total of eighteen participants into two groups. Each group was given a subsubject from a larger issue and asked to create display charts that explained it in detail. Both groups gave

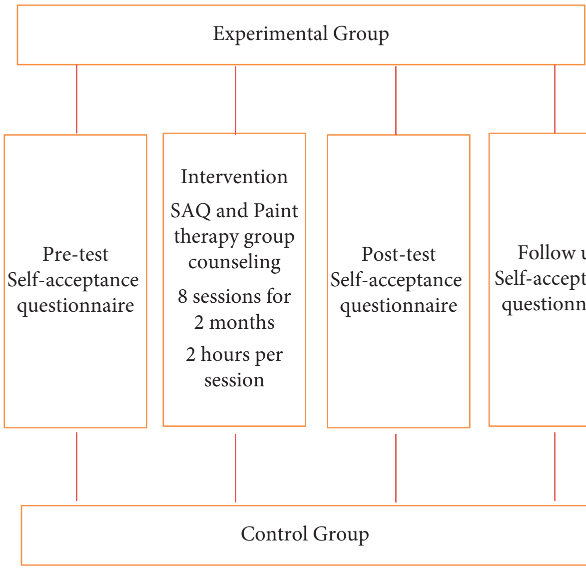

FIGURE 1: Research design.

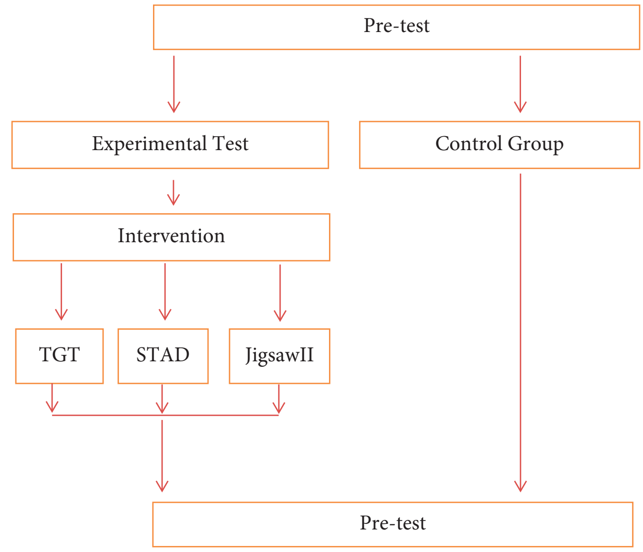

FIGURE 2: Pretest-posttest control group experimental design.

presentations on their respective projects. Figures 2 and 3 illustrate the procedure.

3.3. Data Analysis. The data were analyzed using the SPSS software version 19. The paired-sample t-tests were applied to compare the mean pretest and posttest scores (see Table 1). The independent-samples t-test was used to compare the means of two independent groups.

3.4. Ideas and Scheme of Group Counseling. In [25], the authors described self-acceptance as one of the most important characteristics of self-actualized people. Group counseling for self-acceptance occurred during three phases. Group sessions took place in the group counseling room at the university. At the beginning, group facilitators created an atmosphere of empathy and support by introducing themselves and encouraging each person to share sincerely and openly. The first step was "permission," which meant opening oneself subconsciously. At this stage, the group facilitators guided participants to a state of complete openness or receptiveness through breathing and relaxation exercises. These breathing exercises varied from seconds to minutes depending on the situation. The second step was "awareness." At this point, participants learned about themselves by listening to their body and inner feelings and visualizing their external image, behavior, emotions, and inner thoughts. An individual can express their emotional experience, thoughts, and subconscious feelings through colors without too much conscious thinking. Participants reviewed the works created in the group and interpreted their own works. Discussions that ensued among group members helped them to rediscover themselves and gain a deeper and broader understanding of self. The third step, "acceptance," was based on a comprehensive and objective self-evaluation, including self-acceptance of personal strengths and weaknesses and differences between ideal self

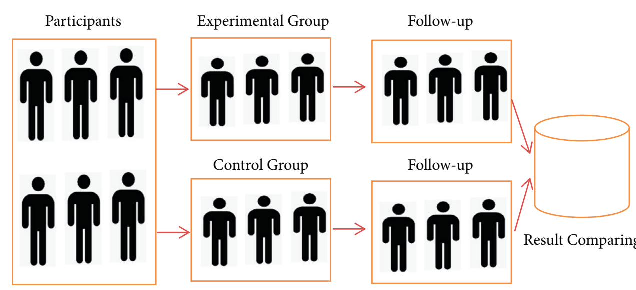

FIGURE 3: Random control trial.

and true self [26]. Painting therapy group counseling scheme is shown in Table 1.

4. Experimental Work and Results

In this section, we explain our experimental work and its results obtained during our work. We have used independent-samples t-test to measure the mean scores difference between achievement scores of control and treatment groups on pretest.

4.1. Comparison of Self-Acceptance between the Experimental Group and the Control Group before and after the Experiment. The SAQ score of the experimental group was higher before the test, with a significant difference in the data ($p < 0.01$). The scores of self-acceptance factor and self-evaluation factor were improved, and statistical results are significantly different ($p < 0.05$). However, the SAQ score, self-acceptance factor, and self-evaluation factor of the control group showed no significant difference before and after the test. Therefore, it is suggested that the PTG counseling intervention has a positive effect on the self-acceptance level of the subjects.

Table 1: Painting therapy group counseling scheme.

Unit	Name of activity	Activity objectives	Main activities
1	Acquaintance is the fate	Establish the group and define the goals and vision of its members.	Snowball self-introduction Develop the group convention Painting the Story of the Name Share works and feelings Make "wish cards"
2	My emotion	Recognize emotions, feel emotions, and express emotions by painting.	Luck Cycle Painting My Emotions Share works and feelings
3	Feel the emotion of the moment	Further perceive emotions, practice to relax, and show the changes of emotions by painting.	You perform, I guess Share your weeks' worth Painting The Emotion of the Moment Share works and feelings
4	My mask	Be aware of myself presented to others and explore the meaning and negative effects of the "mask."	Painting My Mask Share works and feelings
5	True Me	Discover and confront your true self and explore your true needs.	Painting True Me Share works and feelings
6	My shadow	Recognize "shadow" and negative emotions, understand their meaning and resources, and try to accept "shadow."	Painting Bad Me and enjoy music Share works and feelings
7	Self-acceptance	Summarize the methods of self-exploration of group members, introduce Satir's "Iceberg Theory," and use this theory for self-exploration.	Share Satir's "Iceberg Theory" Practice using "Iceberg Theory" for self-exploration and creation Share feelings and discoveries
8	Six elements of change and summarization	Share Satir's "Six Elements of Change," acknowledge the efforts and explorations of the members, review the group, and end the group.	Review group Share the "most memorable work" Summarize and share Exchange wishes and gifts

Comparison of self-acceptance scores of different groups of college students before and after painting therapy group counseling ($x \pm s$) is shown in Table 2.

4.2. Comparison of Follow-Up Self-Acceptance between the Experimental Group and the Control Group Two Months after the Experiment. The follow-up SAQ score after 2 months in the experimental group was higher than that before the test, and there was a statistically significant difference ($p < 0.01$). Among them, the scores of self-acceptance factor and self-evaluation factor were improved with significant differences ($p < 0.05$) which can be seen in Table 3. However, the SAQ score, self-acceptance factor, and self-evaluation factor of the control group showed no significant difference before and after the test. Therefore, it implies that the PTG counseling intervention had a continuous effect on improving the subjects' self-acceptance level.

There is no significant difference between the two groups ($p = 0.01$), as shown in the table below. It means that, before the intervention, both groups were performing at the same level. Independent-samples t-test for pretest of participants achievement is shown in Table 4.

Similarly, Table 5 shows that there is no significant difference between the two groups ($p < 0.05$). Independent-samples t-test for posttest of participants achievement is shown in Table 5. Paired t-test for pretest/posttest is shown in Table 6.

To examine the effect of an intervention on experimental group's accomplishment scores, we used a paired-samples t-test as shown in the table above. The table reveals that the pretest ($M = 9.12$, $\mathrm{SD} = 2.421$) and posttest ($M = 10.25$, $\mathrm{SD} = 1.18$) accomplishment scores were significantly different; $t(50) = -9.17$, $p < 0.001$.

The change trends of the total PTG score were identical for all participants in the intervention class, as shown in Figure 4.

The factual examination of the information utilizing the t-test uncovered that the scores of our proposed scheme in the pretest were fundamentally higher than those in the posttest and follow-up tests for three elements of our work: in the component of posttest and follow-up related tests, the scores of the pretest and posttest were essentially higher than those of the subsequent test. As displayed in Figure 4, the changing pattern of the complete score of the CIAS-R was comparative for all subjects in the experimental group.

4.3. Discussion. The aim of this study was to explore the effects of a paint therapy group counseling intervention on college students' self-acceptance level using an experimental pretest-posttest control group design.

We tested the hypothesis that PTG counseling can improve college students' self-acceptance level. Paired-samples t-tests showed a significant improvement in the experimental group's self-acceptance factor and self-evaluation factor. This result supported our hypothesis. The independent-samples t-test shows that the intervention effect of PTG counseling on college students' self-acceptance level is continuous and significant.

Data analysis of the pretest and posttest PTG counseling showed that, after eight weeks of painting, the level of the total score of the experimental group was significantly improved, as well as the self-acceptance factor and self-evaluation factor. However, the measured data of the control group's subjects did not change significantly before the test and at follow-up and there was no regularity. In the follow-up test conducted two months after the intervention, the self-acceptance score of the subjects in the experimental group was still high, which was significantly different from the self-acceptance score measured before the intervention. This suggests that the PTG counseling intervention had a positive lasting effect on college students' self-acceptance level. Compared with the data before the intervention, the improvement of self-acceptance factors measured two months after the intervention was more than that of self-evaluation, which may improve the self-evaluation level of the subjects in a short period, thus affecting the improvement of self-acceptance level.

Through artistic expressions, PTG counseling greatly reduced the psychological defense mechanism and resistance of group members. Through painting, individuals were able to project unhealthy emotional stressors into works, express their feelings and experiences into the creative process, relieve psychological anxiety, and eliminate problem behaviors [27]. The humanistic treatment orientation created a group member-centered atmosphere so participants felt valued and accepted. Participants reported feeling their inner life energy, learnt to see themselves realistically and objectively, accepted themselves, and finally completed their self-perfection and self-integration. This was a more acceptable approach for sensitive participants who had a greater stress response and low self-esteem. Participants were able to fully open themselves in a relaxed and trusted environment, freely create art, and connect with their subconscious. In this way, their subconscious thoughts were revealed naturally, so that the group leader had a specific understanding of participants' real situation through the colors, lines, shapes, texture, and other expressions of the paintings and so was able to guide them to see and accept their own subconscious contents. Artistic creation has its own process of psychological therapy [28]. Participants expressed emotions through their painting that they found difficult to do ordinarily in their daily life. On the basis of group dynamics theory [29], PTG counseling facilitated group cohesiveness, harmonized the internal atmosphere, stimulated participants' creative thinking process (those who actively participated in the activities), and created a harmonious, warm, and positive atmosphere. Consequently, participants felt accepted and secure enough to trust one another, thus enabling their ability to show their inner feelings and encourage more self-exploration. The words, behaviors, views, and attitudes of group participants became admirable references for other members to emulate. In the process of group counseling, participants constantly adjusted their insights by empathizing with other participants' behaviors, emotions, and thoughts. They also observed the facilitator's communication style, which helped them to learn additional appropriate ways to communicate. In this

Table 2: Comparison of self-acceptance scores of different groups of college students before and after painting therapy group counseling ($x \pm s$).

Survey time	Group	Number of members	Statistics	Self-acceptance factor	Self-evaluation factor	Total self-acceptance score
Before experiment	Experimental group	9		18.11 ± 3.69	19.22 ± 2.17	37.33 ± 4.39
	Control group	9		16.89 ± 2.71	18.22 ± 2.49	35.11 ± 2.15
			t value	0.80	0.91	1.37
			p value	$>.05$	$>.05$	$>.05$
After experiment	Experimental group	9		20.67 ± 4.12	20.11 ± 3.59	40.78 ± 6.91
	Control group	9		16.78 ± 2.77	18.00 ± 2.78	34.78 ± 2.05
			t value	3.19	3.71	3.66
			p value	$<.01$	$<.01$	$<.05$
			d value	1.13	0.66	1.34
Two months after the experiment	Experimental group	9		22.11 ± 2.85	21.56 ± 2.65	43.67 ± 4.64
	Control group	9		16.75 ± 2.75	18.09 ± 2.58	34.84 ± 2.06
			t value	4.06	2.86	4.33
			p value	$<.01$	$<.05$	$<.01$
			d value	1.91	1.33	2.64

Table 3: Satisfaction survey score of experimental group.

Measures	Month 1	Month 2
Self-acceptance score in the experimental group after the test	40.78 ± 6.91 ($t = 3.66$, $p < 0.01$)	43.67 ± 4.64 ($t = 1.0$, $p < 0.05$)
Self-acceptance factor scores	20.67 ± 4.12 ($t = 3.19$, $p < 0.05$)	22.11 ± 2.85 ($t = 4.06$, $p < 0.01$)
Self-evaluation factor scores	20.11 ± 3.59 ($t = 3.71$, $p < 0.01$)	21.56 ± 2.65 ($t = 2.86$, $p < 0.05$)

Table 4: Independent-samples t-test for pretest of participants achievement.

Variable	N	Mean	df	t value	Average covariance (P)
Experimental group	9	9.12	50	0.188	0.01
Control group	9	9.10	50	0.188	0.01

Table 5: Independent-samples t-test for posttest of participants achievement.

Variable	N	Mean	df	t value	Sig.
Experimental group	9	10.25	50	0.188	0.000
Control group	9	10.10	50	2.15	0.000

$p < 0.05$.

Table 6: Paired t-test for pretest/posttest.

		Mean diff.	SD	T	2-tailed sig.
Pair ($p < 0.01$)	Pretest-posttest	−3.200	1.25	−9.17	0.000***

way, the facilitator or group leader can deepen participants' understanding and also learn more about themselves.

4.4. Limitations. Paint therapy group counseling highlighted two significant issues with its implementation. First, to counter any possible stigma of psychological problems,

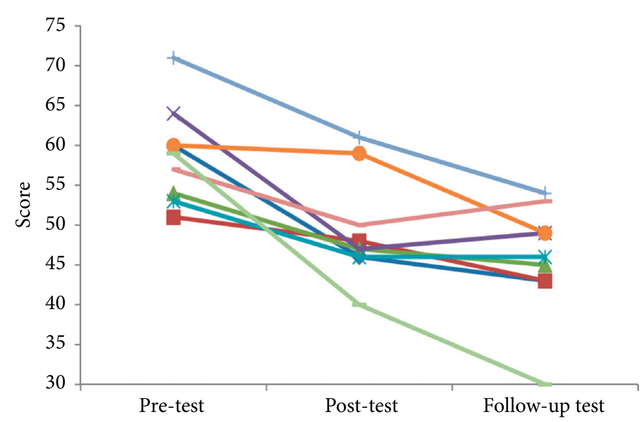

Figure 4: Total score in the experimental group ($n = 9$).

especially in the university setting, the researchers had to rename the group "self-acceptance • painting spiritual growth group" during the recruitment drive. This was intended to spark interest and enthusiasm among college students and encourage them to participate. It was easy to generate empathy among participants in the group, when they experienced similar problems and understood these from other participants' viewpoints. These common feelings allowed participants to lower their defensive mechanisms and engendered trust in the group. Second, aspects of "psychological education" were integrated into group counseling activities to help participants better understand the way of self-acceptance and learn how to change their self-cognition and behaviors. For instance, in the process of PTG counseling, Satir's Iceberg Theory and Six Elements of Change were applied in units 7 and 8 to help participants better understand, accept, and change themselves [30]. Participants' feedback demonstrated attempts to incorporate learning theories into their daily and study life with positive results.

5. Conclusions

This research work presents a paint therapy group counseling intervention for self-acceptance of the students at a university in Guangdong Province. We have conducted a quasiexperiment during which we have created two groups: one is the experimental group and the other is a control group. The participants were randomly and equally assigned to these two groups ($n = 9$ in both groups) and completed pretest and posttest measures of self-acceptance and self-evaluation over 2 months. We have also used a paired-samples t-test to compare the effect of the intervention on the experimental achievement scores of the groups. It can be concluded from the results that paint therapy group counseling had a positive effect on the academic achievement of students enrolled in the subject of education. The outcome suggests that this is an ideal psychological counseling program for college students with low degrees of self-acceptance. On this basis, future researchers may consider exploring alternative forms of group counseling within the higher education settings, which may be more acceptable or culturally relevant to college students, to help them experience better self-acceptance and growth.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Research Article

Study on the Predictive Algorithm of Plant Restoration under Heavy Metals

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Heavy metal pollution of soil is becoming a more serious issue globally. Heavy metal contamination of the soil environment is inevitable as a result of the rapid and extensive growth of industry and agriculture, resulting in unfavorable environmental circumstances for both the flora and fauna. Traditional approaches for collecting field sampling with laboratory testing of soil heavy metals are restricted not only by their time and cost but also by their inability to gather sufficient information about the spatial distribution characteristics of heavy metals in soil over a vast area. The continuous development of the urban industrial processes leads to the degree of heavy metal pollution in urban gardens. For soil monitoring and cleanup, having quick and accurate access to heavy metal concentration data is very crucial and critical. In order to improve the restoration ability of garden heavy metal pollution, a new algorithm to predict plant restoration ability under the garden heavy metal pollution environment is put forward in this study. Firstly, we analyzed the composition of garden heavy metal pollution and the harm of garden heavy metal pollution. Secondly, we identified the restoration technology of garden heavy metal pollution to plants, determine the level of garden heavy metal pollution with the help of the land accumulation index method, and reflect the average pollution water level of garden heavy metal elements with the help of Numero comprehensive pollution heatstroke. On this basis, the plant repairability prediction model was constructed with the help of wavelet function, to predict the plant repairability under garden heavy metal pollution environment and to complete the prediction of plant repairability under garden heavy metal pollution environment. The experimental results show that the proposed method was better than the traditional approaches in terms of prediction accuracy and is also less time-consuming.

1. Introduction

Heavy metals in soil are considered to be one of the most dangerous pollutants in the environment due to their toxicity, persistence, ease of uptake by plants, and lengthy biological lifecycle. These pollutants have the potential to disrupt the regular functioning of the soil, stress crops, and obstruct their growth. These metals can infiltrate the food chain and threaten human health if the crop absorbs them. There is no clear clue of what basically constitutes a heavy metal. Heavy metals are widely recognized as harmful compounds whose deposition in soils and uptake by vegetation have an impact on the fertility of the soil, development of the plant, and production of the plants. Lead (Pb), cadmium (Cd), copper (Cu), zinc (Zn), arsenic (As), manganese (Mn), and chromium (Cr) are some of the most important and accepted heavy metals. All of the mentioned heavy metals have one thing in common: they are very hazardous for both the human health and the environment. For example, Pb had a negative impact on the quality, productivity, and growth of the crops. Also, it is one of the main causes of blood poison in human beings. Cu is another important metal that is helpful for healthy plants growth but is harmful to crops development and becomes a pollutant when it is accumulated in the soil in an excessive amount. Because of its lipid solubility, Cd is one of the most phytotoxic heavy metals that are easily absorbed by plants. When the amount of this metal increases more than 0.25 mg in the vegetables, it becomes a serious threat to human health and can cause various diseases [1]. Keeping in consideration the harm caused by these heavy metals, it is of great interest to check the amount of these metals in soil and monitor it closely, specifically in the agricultural areas, in order to increase the productivity of agriculture. When water and soil are contaminated with heavy metals, major health and environmental challenges are caused. Furthermore, dangerous metal concentrations in soil might cause biodiversity dysfunction by altering soil fertility and biological growth. Heavy metals cannot be dissolved or eliminated by biochemical functions; instead, they can only be changed in terms of their chemical form (known as "speciation"), which might affect their mobilization or immobility [2, 3].

Since the 1970s, due to the rapid development of urbanization and growing population, urban ecosystems and soils have attracted the attention of researchers. The first scholar who put forward the concept of urban soil was Bockheim, arguing that the urban soil is due to human factors and nonagricultural factors, causing the chaotic soil structure and soil pollution, and thus forming the soil with a thickness of more than 50 cm. Due to the continuous acceleration of the urban process, the damage to the land is very serious, especially the heavy metal pollution in the process of garden construction. There is no strict unified definition of heavy metals, but, in general, it refers to metals with a density greater than $5\,g/cm^3$. The elements that constitute heavy metals such as Hg, Cd, Pb, Cr, and As have significant biotoxicity and have an obvious impact on human health, also called "Five-Toxic Elements" [4]. In addition, Cu, Zn, Ni, Mo, Co, Sn, Mn, and other accumulation of heavy metal elements in the human body to a certain extent will also affect human health and lead to chronic poisoning. Soil heavy metal pollution mainly refers to the soil pollution caused by Cu, Zn, Cd, Pb, and other elements. Since 1950, foreign scholars have been concerned about the issue of heavy metal pollution in urban soils, starting from "Minamata disease" and "bone pain" caused by heavy metals Hg and Cd pollution in Japan. In 1970, the researchers of the United Kingdom (UK) analyzed and studied the content level of heavy metals of Pb, Zn, Cu in urban soil and found that the heavy metal contents were closely related to industry and transportation. Hence, heavy metals in urban soil were regarded as one of the indicators of urban pollution. Research on urban soil is gradually becoming a new field of research in environmental science that has a great impact on both plants and humans [5]. As the city contains a variety of sources of pollution, the heavy metal elements are released and invaded into the soil, eventually leading to a polluted urban green soil. To this end, the research on some measures to improve the ability of garden land has become the current key research problem. Researchers in this field have conducted various studies and achieved certain results [6].

Ning et al. [7] proposed the application potential of salt grass in Cd, Pb, and Li polluted salt soil restoration and studied the ability analysis of land salt improvement. His proposed method was a cost-effective method for repairing the contaminated salt soil. The analysis of Cd concentration, the resistance and accumulation characteristics, and the stress of three metal pollutants were studied, in order to explore the application potential of salt grass in the repair of Cd, Pb, and Li polluted salt soil. The results show that, with the concentration of Cd, Pb, fresh and dry weight, low-concentration Li ($\leq$20 mmol/L) treatment promotes the growth of salt grass, while high-concentration Li ($\geq$20 mmol/L) treatment inhibits plant growth. The order of tolerance of Cd, Pb, and Li is Li > Pb > Cd. Cd, Pb, and Li stress may reduce the absorption and transport of Na and K and affect plant growth. On the other hand, the salt grass antioxidase system shows different response mechanisms to Cd, Pb, and Li stress, and a variety of antioxidases cooperate to resist the oxidative toxicity caused by Cd, Pb, and Li stress. The content of salt angle roots and above ground part Cd, Pb, and Li increases with the treatment concentration, where Cd and Pb are distributed by the root and Li in the above ground part. The results show that the stress of Cd, Pb, and Li has strong tolerance and self-regulation, with lithium-rich properties and the potential to repair Cd, Pb, and Li contaminated salt soil. Planting the plant can effectively improve the ability of the salinized land, but the plant planting is affected by the natural environment and other factors and cannot be generally applicable.

Jin et al. [8] proposed a measurement method based on the repair of soil heavy metal pollution. Their proposed method uses the analysis tools brought by the Web of Science (WOS) database, HistCite citation mapping analysis software, VOSviewer visual analysis software, and Origin 9.1 mapping software. Further, they analyze the 21st century (2000–2016) research work done in the desired domain. The article focuses on plant restoration and biore and curing/stabilization; soil heavy metals are cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn), heavy metal arsenic (As), etc. Haichao et al. [9] proposed the spatial and temporal change analysis method of regional habitat quality based on the reconstruction of land-use pattern to predict the land restoration ability. The method uses the InVEST model to reconstruct the habitat quality spatial pattern in the pan-Yangtze River Delta region, calculates the Kappa coefficient of the simulation accuracy, and proves that the method is feasible, on the basis of this method.

Various techniques are used to study soil contamination by heavy metals. The earlier method used was field sampling followed by the chemical analysis which was expensive and ineffective. Being costly, the conventional methods were time-consuming too. The following are some of the contributions of the proposed work:

(i) This study proposes a new plant restoration ability prediction algorithm under the garden heavy metal pollution environment
(ii) Real samples are taken from the gardens soil, after the collection constitution of heavy metals elements in the soil samples was found in order to check the pollution level in it
(iii) Multiple experiments are performed to check the stability and performance of the proposed algorithm

(iv) The experimental results show that the performance of the proposed method is way better than the other approaches in terms of prediction accuracy and forecast time overhead

The rest of the paper is organized as follow: we present a detailed discussion on the analysis of heavy metal pollution in gardens in Section 2. Section 3 illustrates prediction algorithm of phytoremediation capability in heavy metal polluted landscape environment. Section 4 demonstrates the experimental analysis, and finally we conclude our research work in Section 5.

2. Analysis of Heavy Metal Pollution in Gardens

In order to improve the accuracy of the plant restoration ability prediction algorithm under the garden heavy metal pollution environment, the garden heavy metal pollution environment is first analyzed and studied.

2.1. Analysis of Environmental Pollution due to Heavy Metals in Garden. Heavy metal refers to the combination of elements whose density level is above 5.0 g/cm^3 [10]. Zn and Cu are among numerous heavy metal elements that are essential for the growth of plants and animals, but an excessive amount of Zn elements and Cu elements leads to the poisoning of organisms. In the garden heavy metal pollution generally called heavy metals, mainly refers to mercury, lead, chromium, and metal arsenic that are significantly toxic to organisms; it also refers to the general heavy metal elements with a certain toxicity, such as copper, zinc, tin, cobalt, and nickel. The most noteworthy elements in heavy metals are mercury, pot, and chromium. When heavy metals are discharged with wastewater, even small concentrations may cause danger to the soil and plants. Environmental pollution caused by heavy metals is often referred to as heavy metal pollution. Other heavy metal elements such as Cd, Pb, and Cr are toxic to organisms even at very low concentrations, and Cd elements are the most biotoxic metals [11].

Heavy metal pollution in garden soil refers to the phenomenon of bringing heavy metals into the soil, so that the content of heavy metals in the soil is significantly higher than the background content and may cause existing or potential soil quality degradation and deterioration of ecological and environmental conditions. When the soil heavy metal pollution, air pollution, and water pollution are compared with each other, they have concealment, long-term, and irreversible characteristics, but also have the characteristics of great difficulty, high investment cost, and long treatment cycle. The high concentration of heavy metals in the garden soil will harm the growth and development of plants and then affect the output and quality of agricultural products. The harm of heavy metals to plant growth and development mainly depends on the content of heavy metals in the soil, especially the effective content of heavy metals. The main factors influencing the migration and transformation of heavy metals in the soil are the adsorption of colloids on heavy metal, the integration of various inorganic substances and organic ligands, the oxidation and reduction state of the soil, the effect of soil acidity and the ions that coexist with it, and the effect of soil microorganisms on heavy metals. Therefore, the factors affecting the migration and transformation factors and biological effect of heavy metal elements in the soil are the concentration of those elements which forms heavy metals, and it can eventually enter the human body through the "soil-plant system" and food chain, and the pollution of heavy metals affecting human health will cause more serious harm [12].

2.2. HAZOP Analysis of Heavy Metals to Measure Pollution. The following are some of the factors that are considered for the HAZOP analysis of heavy metals to measure the degree of pollution.

(a) Physical and chemical properties and biological activity of garden soil: the existence of most of the heavy metals in the garden soil is relatively stable. After entering the garden soil, it is very difficult to decompose in the process of biological material circulation and energy exchange. Hence, it is very difficult to move out of the soil. Therefore, the physical and chemical nature of the garden soil polluted by heavy metal will change, the natural ecological balance of the soil microbial system will be damaged, the type and number of microorganisms will also decline, the vitality of beneficial microorganisms will also decline, and bacteria will reproduce and spread, causing the spread of garden soil microbial diseases.

(b) Growth and development of garden plants: heavy metals pollution in the garden soil will induce the plant to produce some substances that have toxic and adverse effects on enzyme activity and physiological metabolism. For example, under the stress of some heavy metal elements, the plant will produce overoxygen, packaging, ethylene, and other substances. These substances have certain negative effects on metabolism and enzyme activity in the plant that are sometimes able to cause direct harm to it. For example, some heavy metals can bind to basic amino acids and proteins to cause the deactivation of amino acid protein, seriously resulting in plants death. Sometimes the stress of heavy metals will make plants lack a large number of nutrients (such as N, P, and K) [13] but also reduce the effectiveness of nutrients; the higher content of heavy metals in the soil will inhibit the absorption and transport of calcium, town, and other mineral elements. Heavy metal pollution will also affect the absorption of iron, leading to the decline or lack of plant iron content, causing the abnormal physiological process of iron participation and showing the symptoms of iron deficiency.

3. Prediction Algorithm of Phytoremediation Capability in Heavy Metal Polluted Landscape Environment

3.1. Garden Heavy Metals Pollution in Restoration. Based on the current situation of heavy metals pollution, this paper designed a prediction algorithm of plant soil restoration. Plant restoration techniques include three major types of restoration measures: plant stabilization, plant volatilization, and plant extraction.

In recent years, the plant restoration of garden heavy metals-polluted soil mainly focuses on the following aspects:

(i) Research on the screening of heavy metals super-accumulated plants and the removal effect of those plants

(ii) Activation of plant root secretions in the soil-plant system

(iii) Migration and morphological transformation of heavy metals in the inter-root soil

(iv) Interroot microbial effect and its influence on the morphological transformation and plant absorption of heavy metals

(v) Plant resistance and detoxification mechanism of heavy metals

(vi) Mechanism of superplant absorption, transport, and accumulation of heavy metals

(vii) Restoration role of transgenic plants in heavy metal polluted soil and the breeding and screening of transgenic plants

Plant restoration has the characteristics of in situ repair, with a small disturbance to the soil environment, the governance effect is permanent, while the cost of plant repair is low. When dealing with heavy metal pollution, it can also beautify the environment, purify the air, and improve forest coverage. Posttreatment of plant restoration is relatively easy, the treatment process is basically without secondary pollution, and the recycling of heavy metals is also relatively convenient. Therefore, the treatment of heavy metal pollution soil in plant restoration gardens has a wide application prospect [14].

3.2. Design of Plaintive Plant Ability. In the garden heavy metal pollution, before the restoration of plants, the garden heavy metal pollution is first determined, and the level of the garden heavy metal pollution is determined with the help of the land accumulation index method [15] and is given as follows:

$$P_i = \log_2\left(\frac{a_i}{kb_i}\right), \tag{1}$$

where a_i represents the actual content value of the garden heavy metal elements, b_i illustrates the garden background value of heavy metal pollution, and k demonstrates the pollution index.

The level of garden heavy metal pollution is determined according to the product index method as shown in Table 1.

Table 1: Grade of heavy metal pollution in gardens.

Land accumulation index	Index level	Accumulative degree
5–10	6	Ponderosas
4-5	5	Weight
3-4	4	Serious
2-3	3	Moderate weight
1-2	2	Moderate
0-1	1	Mild
≤0	0	Mild

Heavy metal pollution in the garden contains not only heavy metal materials but also other elements and substances. Therefore, in order to comprehensively reflect the pollution of various heavy metal elements in the garden, numerous comprehensive pollution heatstroke is used to reflect the average pollution water level of heavy metal elements in the garden, as well as the pollution of each heavy metal element [16], given as follows:

$$\begin{aligned} U_i &= \frac{e_i}{s}, \\ U_n &= \frac{\sqrt{U_i U_i^2 + U_i \max_2}}{2}, \end{aligned} \tag{2}$$

where U_i represents the pollution index of garden heavy metal elements relative to the evaluation reference values, while e_i represents the actual value of an element of a garden heavy metal element, where S shows the background values for the evaluation of $U_i U_i^2$ that represents the mean pollution index of heavy metal elements of the garden, while $U_i \max_2$ represents the pollution maximum index of the garden heavy metal elements.

The comprehensive potential ecological risk index of heavy metal elements should also be considered in the pollution of garden heavy metals, which is an important factor that affects the restoration ability of the plants [17]. Therefore, this study also calculates the potential ecological risk of garden heavy metal pollution, given as follows:

$$R_j^i = T_j^i \times G_j^i, \tag{3}$$

$$y_j^i = \frac{G_j^i}{G_n^i}, \tag{4}$$

$$\mathrm{RI} = \sum_{i=1}^{n} R_j^i. \tag{5}$$

In equation (3), R_j^i represents the potential ecological hazard coefficient of garden heavy metal pollution, T_j^i illustrates the toxic coefficient of heavy metal pollution in gardens, while G_j^i demonstrates the single factor pollution index in garden heavy metal pollution. In equation (4), y_j^i represents the measured heavy metal pollution, while in equation (5), RI shows the potential ecological hazard index of heavy metal pollution in gardens.

After determining the correlation index of heavy metal pollution, the means of wavelet function is calculated. The wavelet network is a network model combining wavelet analysis technology and backpropagation neural network. The better wavelet analysis solves the serious lack of resolution in the time domain in Fourier transformation. Wavelet transform is the internal product of the wavelet function and the signal to be analyzed, and the local characteristics of the signal can be analyzed. In the prediction of this paper, the garden heavy metal pollution plants are first set to predict their repairability according to the setting of the plant [18]. The details of plant configuration in garden heavy metal pollution are shown in Table 2.

The plant restoration capabilities predicted in Table 2 are all highly effective plants and are very important in the restoration of garden heavy metal pollution. In the prediction of plant repair capability, the weight of plant repair capability is first determined as follows:

$$T(a) = f_i\left(\frac{\sum_{i=1}^{k} w_{ij}x_i - b_j}{a_i}\right). \tag{6}$$

In equation (6), $T(a)$ represents the weight of plant restoration capabilities [19]. Since the weight of the acquired plant repair capability, the deviation needs to be corrected before the prediction, the help of the nuclear function, and the result is given as follows:

$$U = H(x) = \operatorname{sgn}\left(\sum_{t=1}^{t} w_t K(S_t, x) + b\right). \tag{7}$$

In equation (7), S_t represents the central point of the weight of plant restoration capabilities, while w_t illustrates the correction factor [20, 21].

Then, with the help of the SH algorithm, the objective function is calculated and is given as follows:

$$\min \sum (i, j) \in rs_j^o d_i^h. \tag{8}$$

Considering the above analysis, we constructed the plant restoration ability prediction model with the wavelet function to predict the plant restoration ability under the garden heavy metal pollution environment. Figure 1 shows the concept of the proposed prediction model.

The proposed plant restoration cable predictive model can be calculated mathematically as follows:

$$f_x(a,b) = \frac{\sqrt{a}}{2\pi}\int_{\vartheta}^{\beta} X(u)a(u)d(a). \tag{9}$$

In equation (9), $X(u)$ represents the Fourier transform function, $d(a)$ shows the phase moving along the left and right of the function, while a demonstrates zoom-in and zoom-out capability [22, 23].

According to the constructed prediction model of plant repairability under garden heavy metal pollution environment, optimize the prediction value and improve the ability to predict plant repairability under garden heavy metal pollution environment given as follows:

Table 2: Plant configuration in heavy metal pollution in the garden.

Plant name	Area	Study conditions
Salix babylonica	Willow	Hydroponic experiment
Southeast	Stonecrop	Hydroponic experiment
Nandina	Berberidaceae	Field planting
Cedar	Panacea	Field planting
Mulberry	Mulberry	Field planting
Fragrans	Devilwood	Field planting

$$B(k) = \sum_{i=1}^{j} w_{ij} f(x)\theta. \tag{10}$$

In equation (10), w_{ij} represents the connection weights of the output layer in the wavelet function implicit layer and θ demonstrates the node output value of the implied layer prediction result.

4. Experimental Analysis

This section of the paper represents the experimental results carried out via different experiments. The data was collected from the gardens; that is, samples of the soil were collected from the gardens. All the experiments were performed on a Laptop computer system having the specification of (Intel Core-i7, 7th generation, having a processor of 2.71 GHz, 16 GB of RAM, and the operating system installed on the system was Ubuntu).

4.1. Experimental Scheme. This subsection demonstrates the experimental scheme of the proposed work. In order to verify the prediction ability of the proposed method, we selected the heavy metal pollution area having a length of 200 square meters and different plants and predicted its repairability with the help of the prediction algorithm used in this study. The data was obtained by collecting various samples of the soil. After the collection of data, it was passed through preprocessing stage in order to remove the noise and irrelevant data from the collected dataset. The experimental data is processed in more detail in order to get those features that are more important for the prediction results. The experimental environment is shown in Figure 2.

We performed multiple experiments in order to check the importance and significance of the proposed approach. Here, in this section, we have mentioned the top two experiments along with the parameter values and the results obtained via those experiments.

Table 3 shows the most relevant parameters and their information value in order to conduct experiment 1.

To verify the effectiveness of the proposed method, a comparative study was also conducted with the two other previous approaches. The proposed system was better in terms of accuracy and predicted time overhead as compared to the previous methods. Figure 3 shows a comparison of the prediction accuracy of the proposed system with the other two methods, obtained through experiment 1.

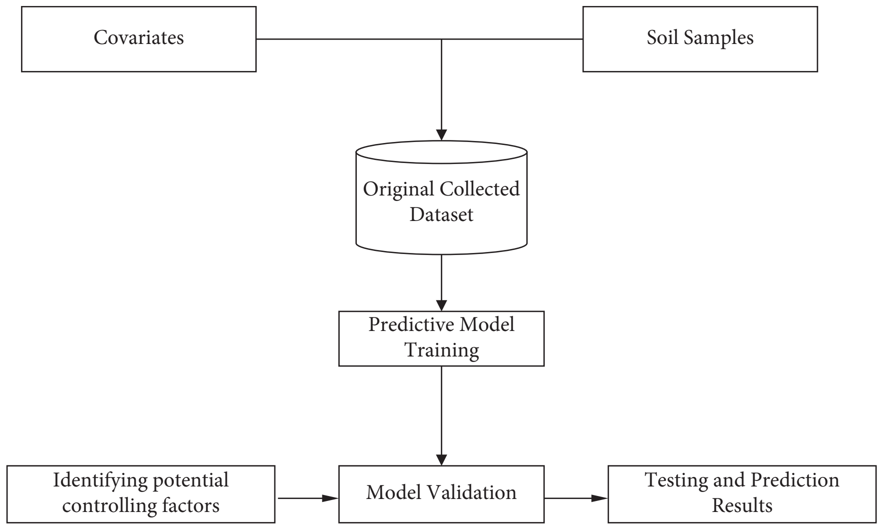

Figure 1: Proposed prediction model of plant restoration.

Figure 2: Local map of the experimental environment.

The analysis of data in Figure 3 shows that the prediction accuracy varies from method 1 to the proposed method. From Figure 3, it is obvious that the prediction accuracy of this method is always higher than 85% and always higher than the other two traditional prediction methods used in this study. The prediction accuracy of method 1 reached the maximum value of 84%, while the maximum prediction accuracy value for method 2 observed was 90%. Compared the prediction methods, the method used in this study and the methods used in the previous approaches, we found that the proposed system was much better than the other methods. Based on the proposed method, the garden pollution level was determined which reflects the average pollution level of the metals. On this basis, the plant repairability prediction model is constructed with the help of wavelet function, to predict the plant repairability under garden heavy metal pollution environment and to complete the prediction of plant repairability under garden heavy metal pollution environment.

In order to further verify the effectiveness of the proposed method, the time overhead of the two previous methods on the plant repairability of the heavy metal pollution area is shown in Figure 4.

Figure 4 shows the results of the three methods used in this study following the same experimental environment. Therefore, the prediction of the heavy metal polluted area is always less than 2 s, and the heavy metal polluted area of the other two methods verified the effectiveness of this method.

The most relevant parameters and their information value for experiment 2 are shown in Table 4.

Table 3: Parameters' design of experiment 1.

Item name	Information value
Plant planting duration (month)	5
Constitute	Two mountain peaks
Specific elevation of the highest peak	132.4 m
Max elevation difference	89.6 m
Slant area	30%
Heavy metal pollution level	Second level
Number of landscape zones	16
Land-use-range shape	Irregular polygon
Rainfall conditions	Autumn and late summer are relatively dry heavy rainfall in late summer and early spring
Aspect change	More obvious
Climate conditions	Long summer, shorter winter, and humid and mild climate
Frost-free season	Around 270 days
Average annual air temperature	16.8°C
Average annual precipitation	1423 mm
Average annual rainfall day	150
Wind direction	Summer is mainly south wind; mainly north wind in winter and spring
Average annual sunshine hours	1720 h
Relative humidity	78%
Cumulative temperature	5344°C
Soil sampling interval (day)	10

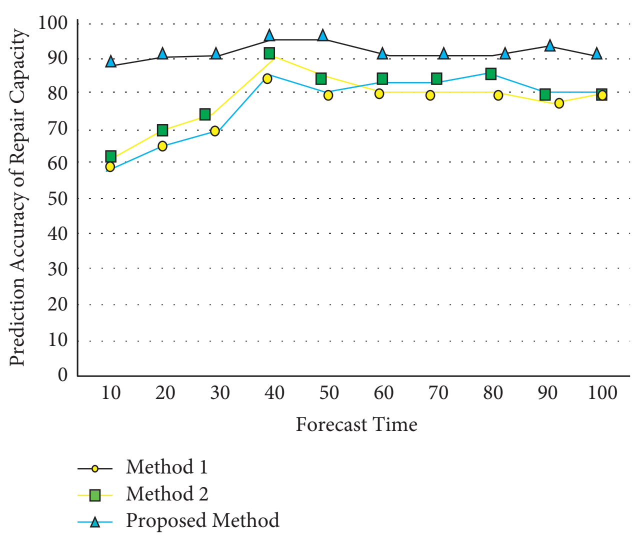

Figure 3: Comparison of prediction accuracy of different methods obtained through experiment 1.

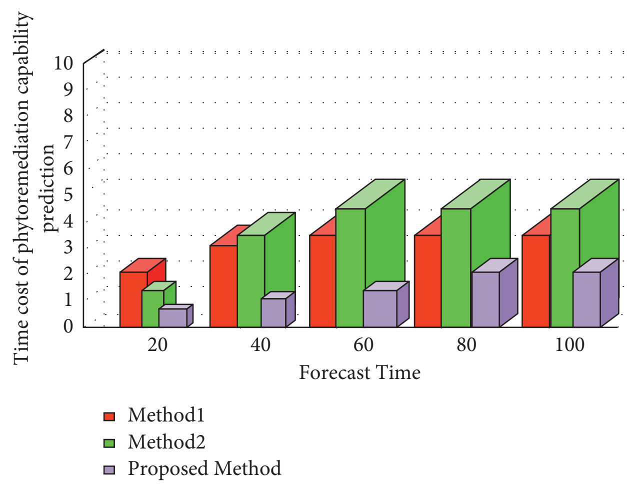

Figure 4: Forecast overhead of the utilized methods.

In order to show the significance and importance of the proposed method, a comparative study was conducted with the two previous approaches. From the experimental results, it was observed that the proposed method outclasses the two previous methods in terms of prediction accuracy and prediction time overhead. Figure 5 demonstrates the analysis of prediction accuracy of the proposed method and the other two previous methods.

Figure 5 shows the analysis of the proposed method and the other two previous approaches used in this study. From Figure 5, it is obvious that the prediction accuracy varies from method 1 to the proposed method. Figure 5 shows that the prediction accuracy of the proposed method is always higher than 86% and always higher than the other two traditional prediction methods used in this study. The prediction accuracy of method 1 starts from 59% and reached a maximum value of 83%, while the prediction accuracy of method 2 starts from 61% and reached a maximum prediction accuracy value of 85%. By comparing the method used in this study and the methods used in the previous approaches, we found that the proposed system was much better than the other methods. Based on the proposed method, the prediction of garden pollution level was determined, and it was found that the prediction accuracy of the proposed method was way better than the other two state-of-the-art approaches. In addition, to show the significance and importance of the proposed method, an analysis of the prediction time overhead of the previous two methods and the proposed method was done. Figure 6 shows the prediction time overhead of the previous methods and the method proposed in this study.

Figure 6 represents the results of all the three methods used in this study, having the same experimental

Table 4: Parameters' design of experiment 2.

Item name	Information value
Plant planting duration (month)	6
Constitute	Two mountain peaks
Specific elevation of the highest peak	135.0 m
Max elevation difference	95.0 m
Slant area	30%
Heavy metal pollution level	Second level
Number of landscape zones	18
Land-use-range shape	Irregular polygon
Rainfall conditions	Autumn and late summer are relatively dry heavy rainfall in late summer and early spring
Aspect change	More obvious
Climate conditions	Long summer, shorter winter, and humid and mild climate
Frost-free season	Around 270 days
Average annual air temperature	20.5°C
Average annual precipitation	1435 mm
Average annual rainfall day	155
Wind direction	Summer is mainly south wind; mainly north wind in winter and spring
Average annual sunshine hours	1720 h
Relative humidity	80%
Cumulative temperature	5340°C
Soil sampling interval (day)	13

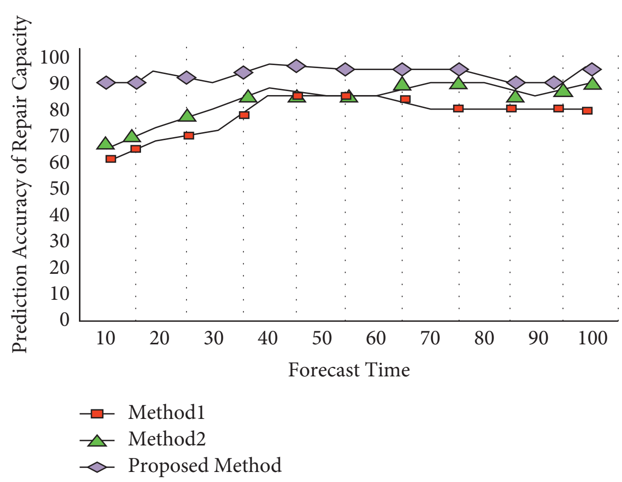

Figure 5: Comparison of prediction accuracy of different methods obtained through experiment 2.

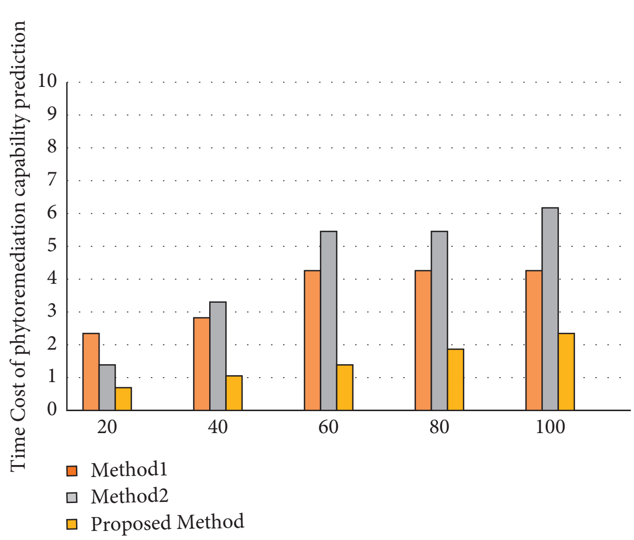

Figure 6: Different methods to forecast the time overhead of experiment 2.

environment. From the experimental results shown in Figure 6, it is quite obvious that the performance of the proposed method is way better than the other two methods used in this study. Thus, the proposed method will be of great help to the agricultural environment and society, in order to predict the plan restoration ability in less time and with higher accuracy.

5. Conclusion

The gradual change and increase in environmental pollution have put everyone's life at a risk and is becoming a serious issue worldwide. Heavy metal pollution in the soil is dangerous for both the human and plants. The traditional methods used for the detection of heavy metals in the soil are atomic fluorescence spectroscopy, photometry, inductively coupled plasma optical emission spectroscopy, chemical analysis, and surface enhanced Raman spectroscopy. The major limitations associated with these approaches are time, material and resources, equipment, prediction accuracy, and they also require a lot of manpower. In order to overcome these issues, this study proposes a new prediction algorithm that predicts the heavy metal pollution in garden soil with a higher prediction accuracy and less time consumption. The proposed method analyzes the status of heavy metal pollution and pollution hazards and determines the composition of heavy metal pollution. In addition, it identifies the restoration technology of garden heavy metal pollution in plants and determines the level of garden heavy metal pollution with the help of the land accumulation index method. Further, it reflects the average pollution water level of garden heavy metal elements with the help of Numero comprehensive pollution heatstroke. On this basis, the prediction model of plant repairability is constructed with the help of wavelet function that predicts the plant repairability under garden heavy metal pollution environment. The experimental results show that the proposed algorithm predicts the heavy metal pollution environment with a higher accuracy and consumes less time for this process. Future work of this study is to design more prediction algorithms that process in much lesser time and to give higher accuracies. The collection of more data samples from different environments and different places and then presenting them to the prediction models is also one of the future studies.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Research Article

Quantitative Analysis of the Impact of Wireless Internet Technology on College Students' Innovation and Entrepreneurship under the Background of "Internet Plus"

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Under the background of "Internet plus," the opportunities and challenges that college students face in the process of innovation and entrepreneurship coexist. College students should make full use of the powerful function of the Internet to excavate the huge business opportunities hidden under the background of "Internet plus." In the context of "Internet plus" of mass entrepreneurship and innovation, the quantitative analysis method is studied in the context of wireless network technology on college students' innovation and entrepreneurship. This paper proposes a combined weight model and an evaluation model based on genetic fuzzy optimization neural network. This research initially establishes an evaluation index system (EIS) by analyzing the influence factors of wireless network technology on college students' innovation and entrepreneurship. In addition, EIS is also analyzed by combining the objective weight of each index obtained by the entropy with the subjective weight of each index obtained by the analytic hierarchy process to construct a combined weight model. A genetic algorithm is used to optimize fuzzy optimization neural networks and establish an evaluation index system of wireless network technology based on genetic fuzzy optimization neural network. To minimize the output error, the function of output error is used as the fitness evaluation function to output the score after several iterations. The experimental results show that the evaluation model can determine the importance of the influencing factors of wireless network technology on college students' innovation and entrepreneurship. It is further evident from the experiments that the proposed model has high accuracy, with the average relative error always less than 1%, which can further improve the effect of quantitative analysis. The proposed model also has a fast convergence speed that can prevent local minima.

1. Introduction

Science and technology are the foundation of a strong country, and innovation is the soul of national progress. The general secretary Xi Jinping pointed out clearly at the meeting of academicians of both chambers that we must firmly grasp the important historical opportunity to promote scientific and technological innovation and unswervingly follow the path of China's independent innovation. The emergence of the concept of "Internet plus" has impacted the traditional industry operation mode and become the new driving force for China's economic transformation and upgrading. As a new force in social development, the rapid development of the Internet provides a new opportunity for college students to innovate and start up businesses [1, 2]. The Internet has built a potential platform for college students' innovation and entrepreneurship. The timeliness of Internet interaction and resource sharing can enable users to interact anytime and anywhere through the Internet so that users can save labor costs to the greatest extent and improve work efficiency under resource sharing. Using the advantages of the Internet for industrial production and logistics, we can improve the efficiency of production and transaction, solve the complex and tedious problems of logistics transactions in production activities, and drive the upgrading and transformation of the industry. It also helps to seize the prominent contradictions and difficulties in industrial production, combine the advantages of the Internet for innovation, and provide a broad platform for college students' innovation and entrepreneurship [3].

The “Internet plus” era provides new opportunities for college students to innovate and start a business. At the same time, it also makes students face the dilemma of innovation and entrepreneurship. College students have less experience in innovation and entrepreneurship, less occupation of social resources, difficulty in obtaining funds, and inaccurate judgment and decisiveness. In the face of the ever-changing market environment, the feasibility integrity of the innovation and entrepreneurship plan formulated by college students is low, the social resources they have are difficult to support them to face the risks of innovation and entrepreneurship and lack of risk control ability, and the business scope has great limitations [4, 5]. The university stage is the key period for students to learn professional skills, and their proficiency in the use of professional skills is low. In the process of innovation and entrepreneurship with the help of the Internet, the understanding of various new technologies is not deep enough, which brings great difficulties to college students’ innovation and entrepreneurship. Therefore, we should deeply analyze the factors that influence the innovation and entrepreneurship of college students under the background of “Internet plus” and the importance of each influencing factor, to take effective strategies to cultivate and improve the innovative and entrepreneurial ability of college students.

Compared with developed countries, the research on innovation and entrepreneurship in China started late. In 1998, Tsinghua University held the first innovation and entrepreneurship competition; in 2002, the Ministry of Education listed Tsinghua University, Renmin University of China, Beijing University of Aeronautics and Astronautics, and other institutions as the pilot institutions of innovation and entrepreneurship education, which means that the innovation and entrepreneurship education in colleges and universities was officially launched in China. In 2015, the State Council put forward the general goal of innovation and entrepreneurship education which is to cultivate the innovative spirit and creativity of college students. To strengthen the implementation of innovation and entrepreneurship education reform, the Ministry of Education pointed out that, since 2016, all colleges and universities should set up innovation and entrepreneurship education courses, which should be included in the credit management. At the same time, many experts and scholars have investigated and studied the current situation and development of college students’ innovation and entrepreneurship and achieved many research results. For example, Tu Jiliang used time series multiple regression analysis as the main means and used the ordered Probit model to interpret the index factors that may affect the innovation and entrepreneurship of college students under the background of “Internet plus,” to provide theoretical support for improving the success rate of college students’ innovation and entrepreneurship [6]. Wang et al. [7] used the network analytic hierarchy process to establish an impact evaluation model of college students’ innovation and entrepreneurship. According to the weight of each index, this paper put forward countermeasures and suggestions for the development of college students’ innovation and entrepreneurship.

This paper studies the quantitative analysis method of the impact of wireless network technology on the innovation and entrepreneurship of college students under the background of “Internet plus.” Starting from the characteristics and development status of college students, the paper constructs an evaluation system with 12 indexes, which is used as input data based on genetic fuzzy optimization neural network evaluation model and outputs the score results after several iterations to determine the importance of each evaluation index. Based on this, this paper puts forward corresponding strategies for the cultivation and improvement of college students’ innovation and entrepreneurship ability to realize the common development of college students’ innovation and entrepreneurship and social economy.

The combination weight model is preferred because it improves the efficacy of the working in the context of accuracy. A fuzzy neural network also known as neurofuzzy system is a particular learning system or machine, which discovers the parameters or factors of a fuzzy system by using estimation methods of neural networks. The fuzzy neural network is preferred to integrate the assets of both FL and neural networks and create them a very powerful hybrid tool. They permit the incorporation of expert information into the method and are measured integrally and more comprehensibly. Moreover, the genetic algorithm method is preferred as it is used for resolving both unconstrained and constrained optimization challenges.

The rest of this paper is organized as follows. In Section 2, the impact of wireless Internet technology on college students was analyzed quantitatively. The proposed approach was comprehensively evaluated through experimental results in Section 3. Finally, the paper is concluded and future research directions are provided in Section 4.

2. Quantitative Analysis of the Impact of Wireless Internet Technology on College Students’ Innovation and Entrepreneurship under the Background of “Internet Plus”

This section provides a detailed description of the proposed analysis and model. The proposed model is a combined weight model based on genetic fuzzy optimization neural network that establishes an evaluation index system (EIS) by analyzing the influence factors of wireless network technology on college students’ innovation and entrepreneurship. A genetic algorithm is utilized to enhance the fuzzy optimization neural networks and finds an evaluation index system of wireless network technology based on genetic fuzzy optimization neural network. The purpose of the model is that college students should fully understand the difficulty of innovation and entrepreneurship, actively participate in practical activities, conscientiously consolidate their professional skills, and rationally plan their goals and objectives, so as to establish a correct sense of innovation and entrepreneurship and strive to contribute to the development of social economy.

2.1. Influencing Factors of Wireless Network Technology on College Students' Innovation and Entrepreneurship. In the era of "Internet plus," the use of the advantages of the Internet to innovate and start a business has become a new driving force for China's economic transformation and upgrading. As a new force for social development, under the social background of mass innovation and entrepreneurship, college students have a growing awareness of using Internet platforms to innovate and start businesses, and many college students have been in the Internet platform through wireless network technology for entrepreneurship, to achieve their value. Under the background of "Internet plus," the factors that influence wireless network technology on college students' innovation and entrepreneurship mainly include the following three aspects. The proposed solution can be automated as well as manual. It depends on the requirements of the application.

2.1.1. Awareness of Innovation and Entrepreneurship. Thinking consciousness is a necessary auxiliary condition in the process of innovation and entrepreneurship. To evaluate the maturity of thinking consciousness of innovation and entrepreneurship talents, we should judge whether they have the following spiritual consciousness:

(1) Adventurous spirit: It is an important part of innovative consciousness, which means being good at finding problems daring to question and breaking the rules.
(2) Divergent thinking: It is manifested in the wide field of thinking. Many psychologists regard this factor as the main feature of creativity. For example, students' awareness of drawing inferences from one instance is the manifestation of divergent thinking.
(3) Sense of responsibility: It is a kind of self-consciousness, the essence of which is to take the initiative to complete the task with hands and brains, which is shown as a serious attitude towards work.
(4) Service consciousness: After the start of innovation and entrepreneurship, entrepreneurs need to have service consciousness, that is, to work for the collective (or other people's) interests or a certain cause.

2.1.2. Innovation and Entrepreneurship Knowledge Level. The higher the knowledge level of college students is, the greater the creativity is and the greater the possibility of entrepreneurial success is. Rich knowledge is the basis of effective practice. The knowledge level is a quantifiable standard in the influencing factors of innovation and entrepreneurship. The following four aspects can be quantitatively analyzed through the test paper.

(1) Professional knowledge: It refers to the mastery of the professional knowledge involved.
(2) Comprehensive knowledge: The acquisition of knowledge is not limited to books, but also through a broader way to improve their knowledge level.
(3) Autonomous learning: In autonomous learning, students are the main body of learning, and it is manifested in the ability of students to collect and process information and analyze and solve problems, as well as the ability to communicate and cooperate.
(4) Cognitive ability: It is often used to test the actual learning ability and working ability of college students, including the investigation of attention and memory. It is a factor that can be quantified through the test paper.

2.1.3. Innovation and Entrepreneurship Practice. Practice is an effective way to test knowledge and ability, and an individual also can solve practical problems. The higher the practical ability is, the richer the practical experience is and the greater the possibility of entrepreneurial success is. When college students carry out innovation and entrepreneurship, most of them end up in failure. The main reason is the lack of practical ability of college students themselves [8, 9], which is mainly manifested in the following four aspects:

(1) Communication ability: It is a person's survival and development of the necessary ability, including listening ability, expression ability, and speculative ability.
(2) Physical fitness: The body is the capital of entrepreneurship, without a healthy physique, abundant physical strength, and energy; it is easy to affect the normal play of innovation and entrepreneurship ability.
(3) Decision-making ability: It refers to the ability to decisively and correctly choose effective methods in the face of problems and opportunities, including the investigation of college students' information extraction ability, prediction ability, and judgment ability.
(4) Practical experience: It refers to the knowledge or skills acquired from many times of practice, and it refers to the personal experience of the final results of practice, including the entrepreneurial practice results of college students and the results of competition activities.

2.2. Evaluation Index System (EIS). The EIS for analyzing the impact of wireless network technology on college students' innovation and entrepreneurship is described in this section. Constructing the evaluation index system of the impact of wireless network technology on college students' innovation and entrepreneurship should follow the principles of scientificity, comprehensiveness, dynamism, and operability [10]. The influencing factors in Section 2.1 are taken as the evaluation index of the system, and the specific evaluation index system is shown in Table 1.

The EIS is categorized into three different layers that are Target Layer, First Level Indexes, and Secondary Indexes. The Target Layer is actually the proposed EIS. The initial level indexes (First Level Indexes) include Awareness of Innovation

Table 1: Evaluation index system (EIS).

Target Layer	First Level Indexes	Secondary Indexes
Evaluation index system of the impact of wireless network technology on college students' innovation and entrepreneurship	Awareness of innovation and entrepreneurship	Spirit of adventure Divergent thinking Sense of responsibility Service consciousness
	Knowledge level of innovation and entrepreneurship	Professional knowledge Comprehensive knowledge Autonomous learning Cognitive ability
	Innovation and entrepreneurship practice	Communication skills Physical quality Decision-making ability Practical experience

and Entrepreneurship, Knowledge Level of Innovation and Entrepreneurship, and Innovation and Entrepreneurship Practice. They are further elaborated and detailed into Secondary Indexes. The Secondary Indexes are the lowest level.

2.3. Construction of Combination Weight Model. The combination weight model is preferred because it improves the efficacy of the working in the context of accuracy. The weight of each index is determined by the combination method of entropy weight model and entropy weight model. The specific steps of the method to determine the weight value of each index in the evaluation model of the impact of wireless network technology on college students' innovation and entrepreneurship are described in Figure 1. Based on the data obtained from the survey, the entropy method is used to obtain the entropy weight of each index in the evaluation index system of the impact of wireless network technology on college students' innovation and entrepreneurship. According to personal experience and background knowledge, the experts judge the importance of each index to different schemes and calculate the subjective weight. The objective weight obtained by the entropy method and the weight of experts' subjective judgment are applied to the combined weight in the best proportion [11–13].

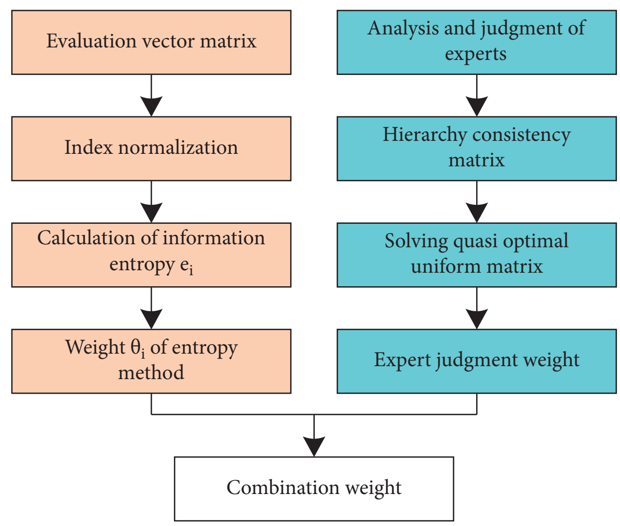

Figure 1: Construction steps of combined weight model.

(1) The evaluation vector matrix is established. The size of the evaluation vector matrix is kept generic $(m*n)$ that is based on the requirements. The evaluation vector matrix can be expressed as a matrix of $m*n$, where m is the number of evaluation indexes and n is the number of schemes. The matrix is shown in equation (1):

$$X=\begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}, \tag{1}$$

where x_{ij} is the index value of the i-th index in the j-th scheme; $i=1,2,\ldots,m$; $j=1,2,\ldots,n$.

(2) Index normalization is represented as equation (2). The index with the bigger the better is as follows:

$$y_{ij}=\frac{x_{ij}-\min(x_i)}{\max(x_i)-\min(x_i)}. \tag{2}$$

Equation (3) represents the indexes with the smaller values:

$$y_{ij}=\frac{\max(x_i)-x_{ij}}{\max(x_i)-\min(x_i)}. \tag{3}$$

The middle excellent index is expressed as equation (4):

$$y_{ij}=1-\frac{\left|\overline{x}_i-x_{ij}\right|}{\max_{i=1,\ldots,m}\left|\overline{x}_i-x_{ij}\right|}, \tag{4}$$

where y_{ij} is the evaluation coefficient of the i-th index in the j-th scheme; x_{ij} is the investigation index value; $\max(x_i)$ and $\min(x_i)$ are the upper and lower limit values of each index; the middle value is generally the best weight value of each index [14].

(3) The weight is determined by the entropy method. The data of the evaluation index system are

standardized, the standardized matrix $Y = \{y_{ij}\}_{m\times n}$ is obtained, and the proportion $p_{ij} = (y_{ij}/\sum_{j=1}^{n} y_{ij})$ of the index value of the j-th region under the i-th index is calculated.

The information entropy of index i can be defined as

$$e_j = -C\sum_{i=1}^{n} p_{ij}\ln p_{ij}, \tag{5}$$

where $C = (\ln n) - 1$ and the weight of index j is $\theta_j = (1 - e_j/\sum_{k=1}^{m}(1 - e_k))$.

(4) Subjective weight based on improved AHP: according to the influence of each index in the evaluation index system, the consistency judgment matrix $R = (r_{ij})_{m\times m}$ is expressed as

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \\ r_{m1} & r_{m2} & \cdots & r_{mm} \end{bmatrix}. \tag{6}$$

Based on the consistency judgment matrix R, the antisymmetric matrix is obtained by mathematical calculation, and then the optimal transfer matrix and quasioptimal consistency matrix are obtained.

(5) Combined weight: the combined weight $W = (w_1, w_2, \ldots, w_m)$ of each evaluation index can be calculated as equation (7):

$$w_j = \frac{\theta_j\cdot\lambda_j}{\sum_{k=1}^{m}(\theta_k\cdot\lambda_k)}, \tag{7}$$

where $0 \le w_j \le 1$, $\sum_{j=1}^{m} w_j = 1$, w_j is the combination weight of j index, θ_j is the entropy weight of the j index, and λ_i is the weight of j index calculated by AHP.

2.4. Evaluation Model of the Impact of Wireless Network Technology on College Students' Innovation and Entrepreneurship. The fuzzy optimization neural network based on a genetic algorithm is used to build the evaluation model of the impact of wireless network technology on college students' innovation and entrepreneurship.

2.4.1. Fuzzy Optimization Neural Network Model. A fuzzy neural network also known as neurofuzzy system is a particular learning system or machine, which discovers the parameters or factors of a fuzzy system by using estimation methods of neural networks. The topological structure of the three-layer fuzzy optimal neural network is described in Figure 2. The input layer of the network is m input nodes, that is, m influence factors; the hidden layer is l hidden nodes, that is, l subsystem; the output layer is single node output [15].

If n samples are set, the input matrix of the network is found using equation (8):

$$R' = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix} = (r_{ij}), \tag{8}$$

where r_{ij} is the normalized number of influence factor i of sample j. The input and output of node k in the hidden layer are described by equations (9) and (10), respectively.

$$I_{kj} = \sum_{i=1}^{m}\left[w_{ik}r_{ij}\right], \tag{9}$$

$$u_{kj} = \frac{1}{1 + \left[I_{kj}^{-1} - 1\right]^2}, \tag{10}$$

where w_{ik} is the connection weight of input layer node i and hidden layer node k.

There is only one node p in the output layer. The input and output of this node are described by formula (11) and formula (12), respectively:

$$I_{pj} = \sum_{k=1}^{l}\left[w_{kp}u_{kj}\right], \tag{11}$$

$$u_{pj} = \frac{1}{1 + \left[I_{pj}^{-1} - 1\right]^2}, \tag{12}$$

where w_{kp} is the connection weight of hidden layer node k and output layer node p.

u_{pj} is the response of fuzzy optimal neural network model to r_{ij}. Formulas (10) and (12) are the special cases of fuzzy variable recognition model when the distance parameter is equal to 1 (Hamming distance) and the optimization criterion parameter is equal to 2 (least square criterion). Set the actual output of sample j as $M(u_{pj})$, and its energy function is described by equation (13):

$$E_j = \frac{1}{2}\left[u_{pj} - M\left(u_{pj}\right)\right]^2. \tag{13}$$

The weight value obtained by the combined weight model is used to adjust the connection weight in the network to minimize E [16, 17]. The formula of the connection weight adjustment between the hidden layer node k and the node p is as equation (14):

$$\Delta w_{kp} = 2\eta u_{kj}^2 u_{kj}\left[\frac{1 - \sum_{k=1}^{l} w_{kp}u_{kj}}{\left(\sum_{k=1}^{l} w_{kp}u_{kj}\right)^3}\right]\left[M\left(u_{pj}\right) - u_{pj}\right], \tag{14}$$

where η is learning efficiency. The formula of connection weight adjustment between input layer node i and hidden layer node k is as follows:

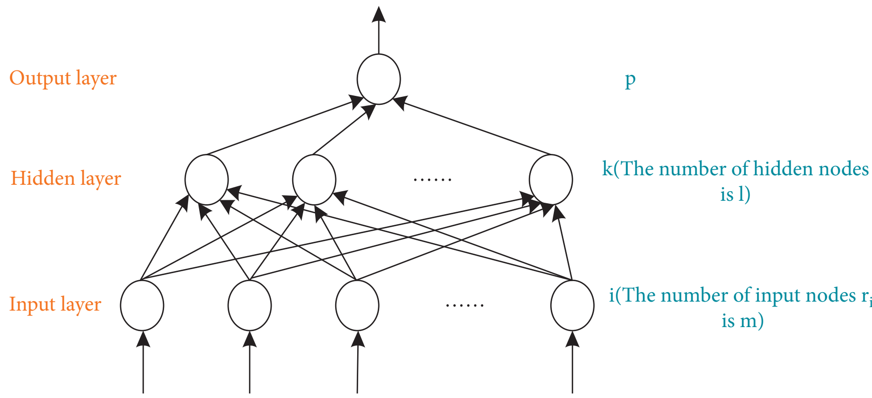

FIGURE 2: Topology of three-layer fuzzy optimal neural network.

$$\Delta w_{ik} = 2\eta r_{ij} w_{kp} u_{kj}^2 \left[\frac{1 - \sum_{i=1}^{m} w_{ik} r_{ij}}{\left(\sum_{i=1}^{m} w_{ik} r_{ij}\right)^3} \right] \delta_{pj},$$
$$\delta_{pj} = 2u_{pj}^2 \left[\frac{1 - \sum_{k=1}^{l} w_{kp} u_{kj}}{\left(\sum_{k=1}^{l} w_{kp} u_{kj}\right)^3} \right] \left[M\left(u_{pj}\right) - u_{pj} \right]. \quad (15)$$

Through the above model, the connection weight value of the network can be determined to minimize the error between the actual output and the expected output.

2.4.2. Fuzzy Optimization Neural Network Model Based on Genetic Algorithm. Aiming at the shortcomings of local minimum and slow convergence speed of neural network model, a genetic algorithm with global search characteristics is integrated into fuzzy optimization neural network algorithm [18, 19].

(1) Determination of the coding method

Floating-point coding has the advantages of large representation range, high precision, large search space, and easy to mix with other methods; because of the accuracy, efficiency, and convenience of calculation, floating-point coding is used in modeling, which also determines the decoding method of the problem.

(2) Initialization of population

On the premise of ensuring the sensitivity of the neural network (i.e., the net input of each node is near zero), to produce as many feasible solutions as possible when the genetic algorithm optimizes the fuzzy optimal neural network weights, the range of the initial population weights is [−2, 2].

(3) Calculation of fitness

The fitness of the genetic algorithm represents the excellent degree of the individual chromosome. The higher the fitness, the better the performance of the chromosome. However, the performance of the network with good initial weights and thresholds is not necessarily good. Only the output error of the neural network after training the initial weights and thresholds for a certain number of times can reflect the excellent performance of the initial weights and thresholds. The training times should not be too many; otherwise, it will lose the significance of using the genetic algorithm to optimize the neural network; when the neural network is trained, the output error of the network changes most obviously in the first dozens of times [20]. The model uses the following function of the output error E of the fuzzy optimal neural network after 25 times of training as the fitness evaluation function, where E is the average relative error between the actual output of the network and the expert score.

$$f(E) = \frac{1}{(1 + 10 \times E)}. \quad (16)$$

(4) Determination of other parameters of genetic algorithm

The model population size is set to 35 and the termination condition is as follows:

$$E \le \varepsilon_1. \quad (17)$$

Moreover, the maximum number of iterations is 15, the roulette is used for selection operation, the uniform arithmetic crossover is used for crossover operation, the probability is 0.6, the uniform mutation is used for mutation operation, and the probability is 0.05.

(5) Determination of neural network parameters

In the modeling process, empirical rules are designed according to the network structure: "thumb rule" which is "pyramid rule" (the number of nodes from input layer to output layer is decreasing).

$$m = \frac{n + l}{2}$$
$$\text{or } m = \sqrt{\frac{n + l}{2}}. \quad (18)$$

Similarly, the hidden layer neuron estimation formula of trial algorithm is as follows:

$$m = \sqrt{n \times l}. \tag{19}$$

The 5-3-1 model structure with better effect is selected through repeated trial and calculation. The end condition of neural network training is $E \leq \varepsilon_2$ or the maximum training time is reached (fine-tuning 2000 times for the approximate optimal value searched by genetic algorithm).

2.4.3. Process of Evaluation Model. In this paper, the Delphi program is used to realize the evaluation model, and the specific process is described in Figure 3.

(1) Determine the coding method, termination conditions, and other parameters of genetic algorithm, and initialize the population.

(2) Decode the solution space, use the fuzzy optimization neural network to train the output error E 25 times, and calculate the individual chromosome fitness using the given formula

$$f(E) = \frac{1}{(1 + 10 \times E)}. \tag{20}$$

(3) Judge whether the termination condition of genetic algorithm is reached ($E \leq \varepsilon_1$) or the maximum number of iterations is 15. If the termination condition is reached, go to step (5); otherwise perform the following steps.

(4) Carry out genetic operation (selection operation, crossover operation, and mutation operation) to generate a new generation of chromosomes, and go to step (2).

(5) Use the neural network to fine-tune the approximate optimal value searched by the genetic algorithm to improve the accuracy of the solution until the neural network fine-tuning termination condition ($E \leq \varepsilon_2$) or the maximum number of training 2000 is reached and the output result is obtained. Flow of the evaluation model is shown in Figure 3.

3. Experimental Results

This section provides comprehensive validation of the proposed study. The proposed model is experimentally tested and verified using authentic data. This study takes 500 senior students of computer major in a university as an experiment object and uses the proposed method to quantify the impact of wireless Internet technology on college students' innovation and entrepreneurship under the background of Internet plus. A questionnaire survey is conducted among 500 students, including 300 boys and 200 girls. Starting from the characteristics and development status of the respondents, the evaluation index in Table 1 is set as the questionnaire survey option to understand the importance of wireless network technology on college students' innovation and entrepreneurship. The results are described in Table 2. Table 2 describes the survey results including the influence factors along with the numbers of girls and boys. The evaluation factors are elaborated in Table 1, which describes the EIS. The EIS is classified into 3 layers. The First Level Indexes include Awareness of Innovation and Entrepreneurship, Knowledge Level of Innovation and Entrepreneurship, and Innovation and Entrepreneurship Practice. They are further elaborated and detailed into Secondary Indexes. The Secondary Indexes are the lowest level.

Table 3 describes the weights utilized in the proposed system. The entropy weight, subjective weight, and combination weight of each index are taken into consideration. The weights are obtained using the entropy and subjective methods in the EIS.

In the evaluation index system of the impact of wireless network technology on college students' innovation and entrepreneurship, each index is used as the input of the evaluation model, and the expert score is used as the output of the evaluation model. For the input data of the evaluation model, the Sigmoid distribution transformation is used to implement the normalization processing, because the Sigmoid distribution transformation has the function of data compression, which can not only reduce the abnormity of some abnormal data and reduce the influence of the abnormity of the abnormal data on the modeling but also retain the role of the abnormal data in the modeling, making the results more scientific and reliable.

The equation of Sigmoid distribution transformation is as follows:

$$y_i = \frac{1}{1 + be^{-ax_i}}, \tag{21}$$

where x_i is the original evaluation index value, y_i is the evaluation index value after conversion, and a and b are the parameters to be determined. The value range of the expert score of the output results of the evaluation model is [0, 5], which is directly transformed into [0, 1] by linear scaling transformation: $y_i = x_i/5$. Repeat the test 5 times, and the scoring results of each index in the evaluation index system are described in Table 4.

Table 4 describes that the score of every index is proportional to the weight of the respective index that is elaborated in Table 3. The larger the weight value is, the higher the corresponding score is, and the index would be higher too. The scores of the five tests are close to the actual situation reflected in the questionnaire survey, and the evaluation results are accurate and reliable. The top three are practical experience, divergent thinking, and decision-making ability. Therefore, in the process of innovation and entrepreneurship, college students should pay special attention to the cultivation and promotion of these five aspects of ability. Comparing these data, it can be concluded that the evaluation model can determine the importance of wireless network technology to the factors affecting the innovation and entrepreneurship of university students and can achieve a quantitative analysis of the impact of wireless Internet technology on college students' innovation and entrepreneurship under the background of "Internet plus," and the analysis results are of high accuracy and reliability.

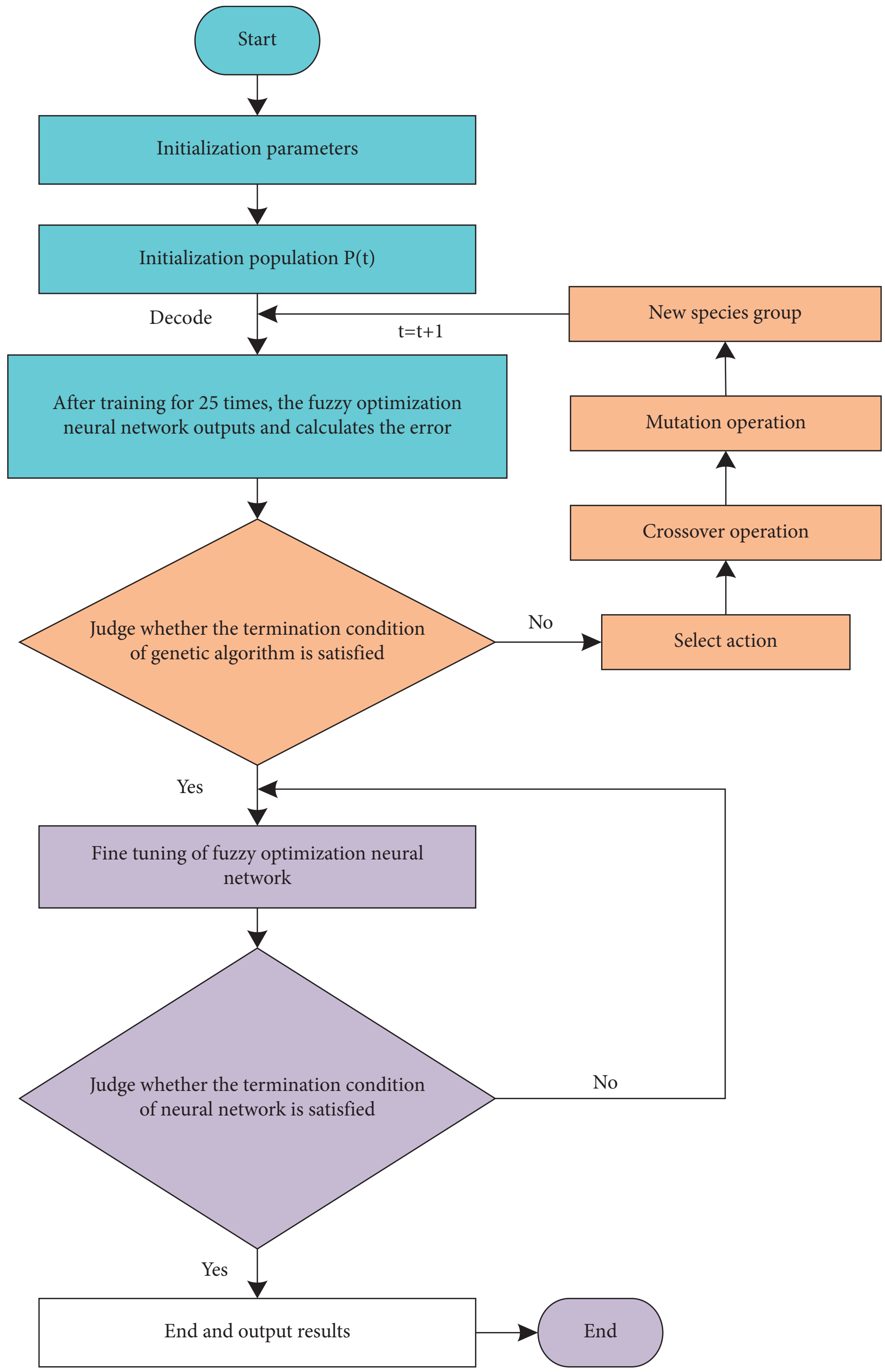

Figure 3: Flow of evaluation model.

To further analyze the performance of the proposed method, the average convergence time of the fuzzy optimal neural networks before and after improvement under different iterations is analyzed experimentally. The results are shown in Figure 4. It can be seen from the analysis of Figure 4 that the average convergence time of the improved fuzzy optimization neural network is extremely stable, always less than 0.4 s; when the number of iterations is less than 40, the average convergence time of the improved fuzzy optimization neural network is relatively low; when the number of iterations is more than 40, the average convergence time rises rapidly and then gradually tends to be stable; when the number of iterations increases to 160, the average convergence time increased to about 1.1 s. Comparing these data, it can be concluded that the improved fuzzy optimization neural network based on a genetic algorithm has a faster convergence speed. Integrating a genetic algorithm into fuzzy optimization neural networks can improve the

Table 2: Survey results of importance of influencing factors.

Influence factor	Number of boys	Number of girls
Spirit of adventure	28	14
Divergent thinking	38	27
Sense of responsibility	12	10
Service consciousness	18	11
Professional knowledge	33	22
Comprehensive knowledge	32	20
Autonomous learning	29	16
Cognitive ability	10	9
Communication skills	20	13
Physical quality	5	6
Decision-making ability	35	23
Practical experience	40	29
Spirit of adventure	28	14

Table 3: Evaluation index weight results.

Evaluating index	Entropy weight	Subjective weight	Combination weight
Spirit of adventure	0.0456	0.0351	0.0102
Divergent thinking	0.2746	0.2208	0.3890
Sense of responsibility	0.0151	0.0364	0.0034
Service consciousness	0.0325	0.0375	0.0077
Professional knowledge	0.0645	0.0392	0.0162
Comprehensive knowledge	0.0585	0.0324	0.0120
Autonomous learning	0.0584	0.0312	0.0116
Cognitive ability	0.0151	0.0330	0.0031
Communication skills	0.0456	0.0309	0.0089
Physical quality	0.0090	0.0330	0.0018
Decision-making ability	0.0888	0.1794	0.1022
Practical experience	0.2325	0.2898	0.4323

Table 4: Scoring results of evaluation indexes.

Evaluating index	1	2	3	4	5
Spirit of adventure	0.59	0.58	0.59	0.57	0.57
Divergent thinking	0.8	0.81	0.83	0.81	0.82
Sense of responsibility	0.46	0.45	0.45	0.47	0.46
Service consciousness	0.5	0.49	0.51	0.51	0.52
Professional knowledge	0.69	0.70	0.68	0.71	0.69
Comprehensive knowledge	0.65	0.66	0.65	0.64	0.66
Autonomous learning	0.61	0.62	0.60	0.61	0.62
Cognitive ability	0.42	0.41	0.42	0.43	0.41
Communication skills	0.55	0.54	0.55	0.56	0.55
Physical quality	0.31	0.32	0.30	0.31	0.32
Decision-making ability	0.78	0.77	0.76	0.77	0.78
Practical experience	0.85	0.86	0.85	0.84	0.86

convergence speed of fuzzy optimization neural networks and prevent local minimum.

The index of the evaluation is introduced into the training model of the network. The required learning efficiency is set to 0.01 and the expected error is set to 0.001 to have the improved performance. Moreover, the maximum number of training is 25 times to prove the efficiency of the repetition end condition of the assessment model. The results are depicted in Figure 5.

It can be seen from the analysis of Figure 5 that when the number of iterations reaches the 15th, the average relative error is $0.00099 < 0.001$, and the iteration stops, meeting the iteration termination conditions of the evaluation model. Therefore, it is reasonable to set the maximum number of iterations to 15 in the evaluation model. At this time, the network obtained by training is used to simulate the evaluation indexes, and the score simulation values are obtained. The 12 evaluation indexes are represented by numbers 1–12, respectively. The comparison results between the score simulation values and the actual values are described in Figure 6.

According to the analysis of Figure 6, the changing trend of the simulated score obtained through training is completely consistent with the actual value and fluctuates slightly around the actual value, which is also in line with the actual situation of the questionnaire survey in Table 2. Therefore, the proposed method can be used to quantify the accuracy of the Internet plus technology in the context of Internet plus.

Under different iterations, this paper quantitatively analyzes the average relative error of the impact of wireless network technology on college students' innovation and entrepreneurship and designs a comparative experiment. It selects the correlation analysis and evaluation method of innovation and entrepreneurship education resources and science and technology innovation service function of local colleges and universities in [6] and the emerging evaluation method based on network analytic hierarchy process in [7] as a comparison method of the methods in this paper; the average relative error results of quantitative analysis of the three methods are described in Figure 7.

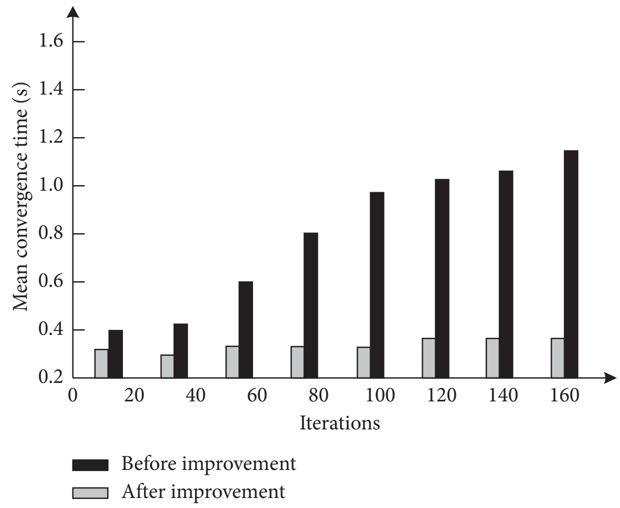

Figure 4: Comparison of average convergence time results.

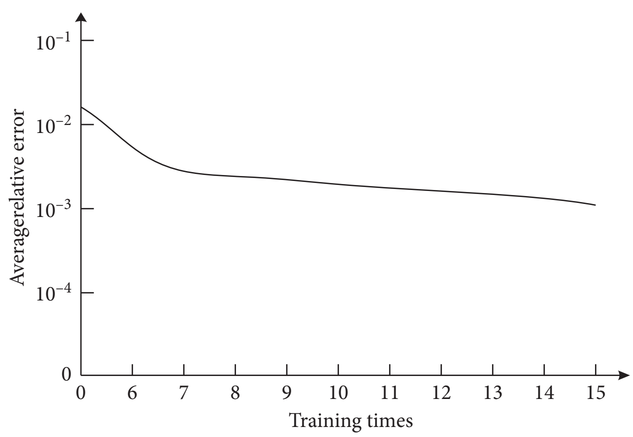

Figure 5: Iteration stop condition.

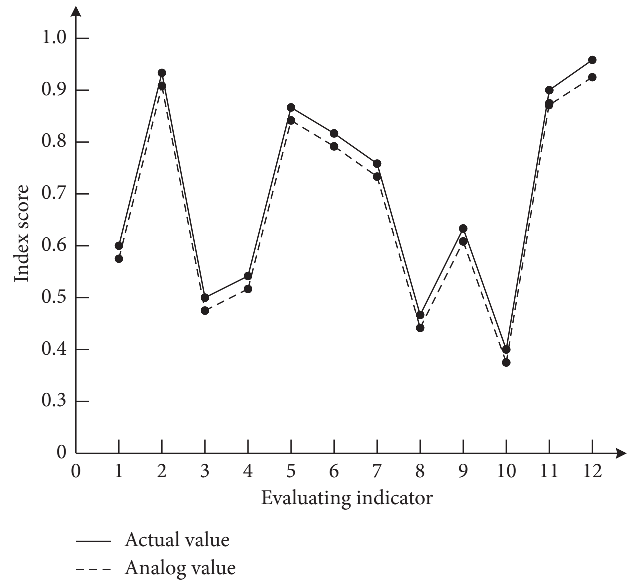

Figure 6: Comparison of simulated value and actual value.

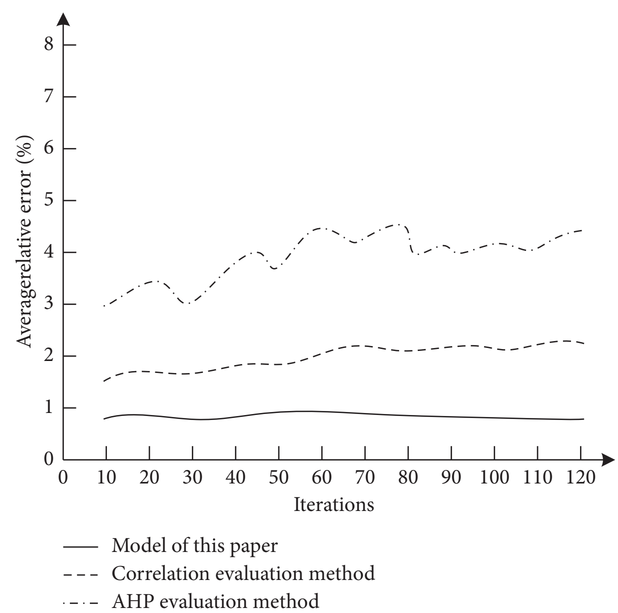

Figure 7: Comparison of average relative error results.

According to the analysis of Figure 7, compared with the other two methods, the average relative error of the proposed method always keeps the lowest changes smoothly and is controlled below 1%; the average relative error of the correlation evaluation method fluctuates obviously in the range of [1%, 3%]; the average relative error of analytic hierarchy process evaluation method fluctuates greatly in the range of [2%, 6%] and is extremely unstable. Comparing these data can show that the proposed method has a good quantitative analysis effect on the impact of wireless network technology on college students' innovation and entrepreneurship and can accurately judge the importance of each influencing factor, followed by the correlation evaluation method, the quantitative analysis effect of AHP evaluation method is the worst, and the performance needs to be improved.

The performance analysis of the proposed model is provided with other models. Only 2 other models are considered due to the domain relevance. The models are examined from four features that are population size, iteration times, network fine-tuning times, and correlation. The comparative analysis is provided in Table 5.

Table 5: Performance comparison.

Performance index	Proposed model	Correlation	AHP
Population size	40	50	60
Iterations	15	1250	1024
Network fine-tuning times	<2000 times	—	—
Relevance	Above 0.96	Above 0.92	Above 0.90

According to Table 5, the population size of the correlation evaluation method and analytic hierarchy process evaluation method is 50 and 60, respectively. The correlation between model training results and expert scoring results is above 0.92 and 0.90, respectively, which requires more than 1000 iterations to obtain a better solution. Compared with the other two methods, the population size of the proposed method is 40, which only needs 15 iterations, and then, the neural network is used to fine-tune about 2000 iterations to get a better solution. Therefore, it can be explained that the overall performance of the proposed method has more advantages and can better achieve the quantitative analysis of the impact of wireless Internet technology on the innovation and entrepreneurship of college students under the background of "Internet plus."

4. Conclusion

This paper constructs a combined weight model and an evaluation model based on genetic fuzzy optimization neural network to realize the quantitative analysis of the impact of wireless Internet technology on college students' innovation and entrepreneurship under the background of "Internet plus." The experimental results show that the proposed method can determine the importance of each evaluation index that has a good quantitative analysis effect, and the analysis results are accurate and reliable. The evaluation model applied in this paper has a fast convergence speed that can prevent local minima, the iteration termination condition has high rationality, the ideal solution can be obtained after 15 iterations, and the overall performance advantage is significant. The proposed method has high accuracy, with the average relative error always less than 1%, which can further improve the effect of quantitative analysis. The college students should fully understand the difficulty of innovation and entrepreneurship, actively participate in practical activities, conscientiously consolidate their professional skills, and rationally plan their goals and objectives, so as to establish a correct sense of innovation and entrepreneurship and strive to contribute to the development of social economy.

Data Availability

The data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author declares that he has no conflicts of interest.

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Research Article

Research on Visual Image Texture Rendering for Artistic Aided Design

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The rendering effect of known visual image texture is poor and the output image is not always clear. To solve this problem, this paper proposes a visual image rendering based on scene visual understanding algorithm. In this approach, the color segmentation of known visual scene is carried out according to a predefined threshold, and the segmented image is processed by morphology. For this purpose, the extraction rules are formulated to screen the candidate regions. The color image is fused and filtered in the neighborhood, the pixels of the image are extracted, and the 2D texture recognition is realized by multilevel fusion and visual feature reconstruction. Using compact sampling to extract more target features, feature points are matched, the coordinate system of known image information are integrated into a unified coordinate system, and design images are generated to complete art-aided design. Simulation results show that the proposed method is more accurate than the original method for extracting the information of known images, which helps to solve the problem of clearly visible output images and improves the overall design effect.

1. Introduction

Software design and hand-drawn design are usually used in art design. With the rapid development of multimedia technology, art design is more and more inclined to be combined with computer technology, resulting in various auxiliary design tools and software design functions [1]. Various software design tools can improve the quality of work by reducing the cost of manual design. At the same time, designing samples using 2D and 3D software design models enrich the creativity of visual effect [2] and can better represent the designer's design concept and innovative ideas, change the original form of artistic design, improve the working mode of artistic design, and bring earth-shaking changes to traditional artistic design.

In computer science, the scene visual understanding is one of the most widely used technologies in the field of art design. Visual comprehension of scene allows the use of computer to replace human eyes and brain to perceive, recognize, and understand 3D scenes and objects in the real world [3, 4]. It is used to analyze the complex distribution of objects in the scene's image by combining with natural language processing for accurately describing the information obtained in a reasonable manner. The main objective of visual comprehension is to allow the designers to extract the scene information. Applying the visual comprehension algorithm to the visual scene of artistic aided design can help the designer to solve the problem when the output image is not clear because of the imprecise information.

With the development of image processing technology, 2D texture recognition of color image is carried out by using image processing technique from computer vision. Moreover, 2D texture feature extraction and analysis method of color images is combined to analyze the texture feature of color images, improve the image quality and detection ability of color images, study the 2D texture recognition method of color images, and improve the accurate analysis and 3D feature resolution ability of color multitexture image. In [5], the authors used a combination of macro- and local aspects to obtain multiscale data information for building an image information model. The authors in [6] put forward a method of image segmentation based on the induction and application of multifeature information in remote sensing images. This method combines the features of spectrum, texture, and shape, respectively. In [7], the authors put forward a method of remote sensing image segmentation by combining spectral and texture features, which can improve the segmentation efficiency and accuracy of different objects.

Edge sharpening feature decomposition, scale decomposition, and multimode feature reconstruction methods are used to realize 2D texture recognition of color images [8]. However, the traditional methods for 2D texture recognition face numerous challenges such as low precision and bad self-adaptive ability. Hence, in this study, 2D texture rendering based on computer vision is proposed to detect the saliency areas of the 2D texture image.

The rest of this paper is organized as follows. In Section 2, graphics rendering is discussed which is the building block of 2D texture rendering. In Section 3, color multitexture image acquisition and regional fusion filtering is discussed. The experimental results and analysis are provided in Section 4. Finally, this paper is concluded and future research directions are provided in Section 5.

2. Graphics Rendering

Rendering pipeline is a conceptual model in computer graphics that describes the steps a graphics system needs to perform for rendering a 3D scene onto a 2D screen [9]. For this purpose, we first discuss graphical rendering process in Section 2.1 followed by vertex processing and 3D observation in Section 2.2.

2.1. Graphical Rendering Process. Commonly referred to as a rendering pipeline, it is a series of data processing for application's data into the final rendering of an image [10]. The rendering process is shown in Figure 1. First, the vertex and attribute required for the geometry is set on the client side of the application, and then, the data are entered into a series of shader stages for processing. The output of one element is used as an input for the next stage/element, resulting in an image that can be rendered to a 2D screen. Next, the rendering pipeline can be divided into several main stages, namely, vertex processing, rasterization, slice processing, and output integration operation.

During the vertex processing phase, vertices and primitives, such as conversion operations, stored in the buffer are processed. In the rasterization phase, the updated pixels are passed to the rasterized unit upon clipping [11, 12] by converting each pixel into a set of slices. Here, the slice is defined as a set of data, i.e., pixels that can not only be placed in the frame cache but also can be culled out and the pixels in the color buffer defined as a memory space that stores the pixels displayed on the screen. During chip processing, the chip testing is mainly carried out, and then, the color value of the chip is determined by various operations of the chip shader. During the output merge phase, the pixels in the slice and color buffers are compared or merged, and the color values of the pixels are updated [13].

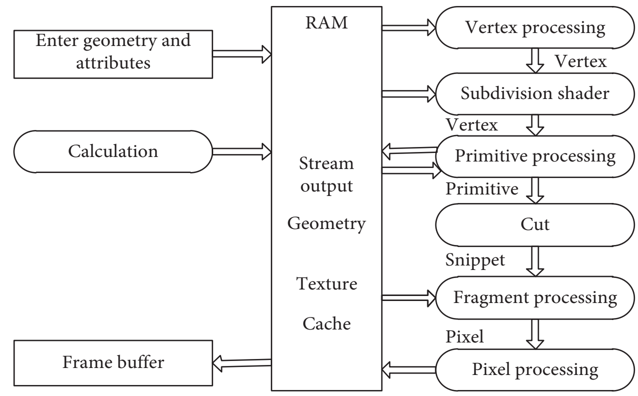

Figure 1: Rendering a graph.

2.2. Verx Processing and 3D Observation. Vertex processing and 3D observation perform various 3D geometric transformation operations on each input vertex stored in the buffer. The vertex processing stage is programmable. Based on the vertex processing transformation operation, 3D objects can be transformed from object space to clipping space. The transformation pipeline flow is shown in Figure 2.

Each object has a local coordinate system, or it can be assumed that each object is defined in its own object space. Also, multiple objects can be integrated into a single world space provided that the coordinate transformation takes the form

$$\begin{aligned} x' &= a_{xx}x + a_{xy}y + a_{xz}z + b_x, \\ y' &= a_{yx}x + a_{yy}y + a_{yz}z + b_y, \\ z' &= a_{zx}x + a_{zy}y + a_{zz}z + b_z. \end{aligned} \tag{1}$$

The coordinates x', y', and z' are derived from the linear transformations of the original coordinates x, y, and z, which are called affine transformation. Translation, rotation, scaling, reflection, and tangent are special cases of affine transformations. Any affine transformation can always be expressed as a combination of these five transformations [14].

In the 3D homogeneous coordinate representation, the 3D translation of the coordinate position can be expressed in a matrix form using

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & t_x \\ 0 & 0 & 0 & t_y \\ 0 & 0 & 1 & t_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}. \tag{2}$$

In the 3D scene environment, the model object can be transformed by translating its vertex coordinates.

The three-dimensional rotation operation requires defining the corresponding rotation axis. First, the three-dimensional z-axis rotation needs to be obtained using equation (3). Next, the secondary coordinate is obtained using equation (4):

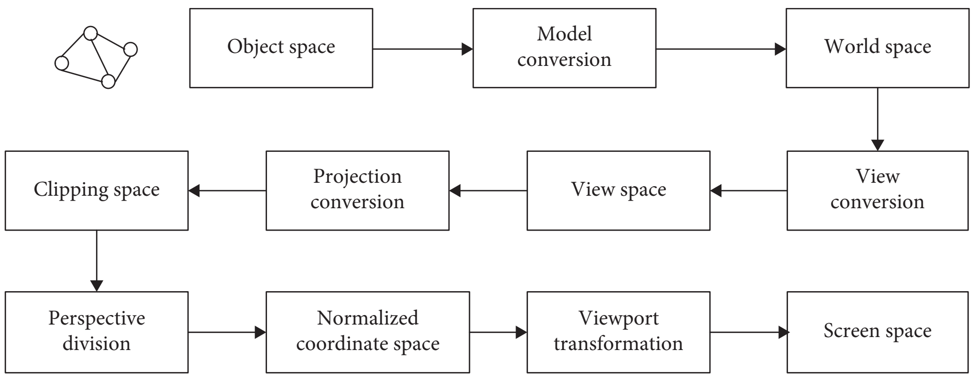

Figure 2: Transformation pipeline flow.

$$\begin{aligned} x' &= x \cos\theta - y \sin\theta, \\ y' &= x \sin\theta + y \cos\theta, \\ z' &= z, \end{aligned} \tag{3}$$

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}, \tag{4}$$

where θ is the angle of rotation.

The equation for rotating around the other two axes can be replaced by the coordinate parameters x, y, and z in equation (3):

$$x \longrightarrow y \longrightarrow z \longrightarrow x. \tag{5}$$

Using equation (5), the transformation equation for rotation around the x and y axes can be obtained as follows:

$$\begin{aligned} x' &= x, \\ y' &= y\cos\theta - z\sin\theta, \\ z' &= z\sin\theta + z\cos\theta, \\ x' &= z\sin\theta + x\cos\theta, \\ y' &= y, \\ z' &= z\sin\theta + x\cos\theta. \end{aligned} \tag{6}$$

Three-dimensional scaling can be represented by the following matrix:

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} t_x & 0 & 0 & 0 \\ 0 & t_y & 0 & 0 \\ 0 & 0 & t_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}. \tag{7}$$

Among them, the scaling parameters t_x, t_y, and t_z are arbitrary positive values that are prespecified. The display of the scaling transformation relative to the origin is expressed as

$$\begin{aligned} x' &= x \cdot t_x, \\ y' &= y \cdot t_x, \\ z' &= z \cdot t_z. \end{aligned} \tag{8}$$

When the object is modeled, it has its own local coordinate system and belongs to its own object space. In the rendering pipeline, the first task is to integrate the model objects of the independent object space into the world space, i.e., the world coordinate system. The world space can be regarded as the coordinate system of the entire virtual scene. The integration process is to apply model conversion, i.e., a model conversion matrix (Mmod) is obtained by multiplying the matrices of the above series of affine transformations, and the position coordinates of the model object in the object space are multiplied by Mmod to obtain the model object in the position coordinates of world space.

3. Color Multitexture Image Acquisition and Regional Fusion Filtering

In this section, first, we discuss the color multitexture image acquisition for rendering followed by plane projection of the area to be mapped. Finally, we discuss the procedure to calculate the coordinate of texture.

3.1. Color Multitexture Image Acquisition. To realize the two-dimensional texture recognition of color images based on computer vision, first, we build a color multitexture image acquisition model [15], use the local window feature detection method to extract the contour feature points Q and P of the color multitexture image, and combine the correlation. According to the fusion rule [16], the maximum value pixel_A of the two-dimensional edge pixel feature components of the color multitexture image is

$$\text{pixel\_}A = \max\left(\sum_{i=1}^{8} (Q - P)\right). \tag{9}$$

Using the local information entropy fusion model for color multitexture image collection, extract the contour points of the color multitexture image, perform local information entropy fusion processing on the color multitexture image, extract the active contour model of the color multitexture image, and combine the color multitexture image The regional features of the active contour are matched with edge pixel features, and the local information entropy $\mathrm{rect}(t)$ is extracted, and the output of the pixel feature quantity collected by the color multitexture image is reflected:

$$u(t)=\frac{1}{\sqrt{T}}\mathrm{rect}\left(\frac{t}{T}\right)\exp\left\{-j\left[2\pi K\ \ln\left(1-\frac{t}{t_0}\right)\right]\right\}. \tag{10}$$

In equation (10), the pixel feature quantity $|t|\leq 1$ and K are the number of pixels and j represents the singular point of the boundary of the color multitexture image. Assume that the position information associated distribution length of the color multitexture image is $L=x_{\max}-x_{\min}$ and the width is $W=y_{\max}-y_{\min}$ and $H=z_{\max}-z_{\min}$. Set the number of super-pixels to obtain the one-dimensional histogram distribution of the color multitexture image, determine the number of super-pixels K, and combine the scattering model to obtain the 2D texture feature of the color multitexture image. Splines' biorthogonal wavelet transform method is used to obtain the texture high frequency component, according to the USV decomposition result, which realizes the feature decomposition and 2D texture recognition of the color multitexture image.

3.2. Plane Projection of the Area to Be Mapped. Assume that the three noncollinear points in the area to be mapped are point P, point M, and point N, where P controls the source point of texture mapping that corresponds to the coordinate origin of the two-dimensional texture image, and the vectors $\overline{PM}$ and $\overline{PN}$ control the direction of texture image μ and axis v, respectively.

From the plane equation $A(x-x_o)+B(y-y_o)+C(z-z_o)=0$, it is known that, to determine a plane, one needs to know the coordinate ruler $P(x_o,y_o,z_o)$ of any point on the plane and the plane normal vector $M\{A,B,C\}$. Given that the three vertices of the plane are P, M, and N, set the vectors $M_1=M-P$ and $M_2=N-P$, and then, calculate the cross product of the vectors to obtain the plane normal vector $M=M_1\times M_2$. In this way, a plane composed of points P, M, and N is obtained, which serves as the reference plane T of the projection.

Knowing that the coordinate of any point in the area to be mapped is $Q_i(x_i,y_i,z_i)$, the coordinate $Q_i'(x_i',y_i',z_i')$ of its projection point on the reference plane T needs to be obtained. According to the simultaneous equations,

$$\begin{cases} A(x-x_o)+B(y-y_o)+C(z-z_o)=0,\\ x_i'=x_i+kA,\\ y_i'=y_i+kB,\\ z_i'=z_i+kC. \end{cases} \tag{11}$$

The value of k can be obtained using

$$k=\frac{A(x_o-x_i)+B(y_o-y_i)+C(z_o-z_i)}{A^2+B^2+C^2}. \tag{12}$$

Thus, the projected coordinate Q can be obtained in this fashion, i.e., $Q_i'(x_i',y_i',z_i')$.

3.3. Texture Coordinate Calculation. After projecting the vertices in the area to be mapped onto the reference plane T, a coplanar three-dimensional point set is obtained. According to this coplanar point set, a two-dimensional coordinate system S-T can be established, as shown in Figure 3.

The origin of the S-T coordinate system is the first point P of the three vertices in the reference plane. Take the side $PM=M-P$ as the horizontal axis, the length of the horizontal axis is $|\overline{PM}|$, and the length of the longitudinal axis is $|\overline{PN'}|$:

$$\left|\overline{PN'}\right|=|\overline{PN}|\cdot\cos\alpha, \tag{13}$$

where α is the angle between the vector PN and the ordinate. Given that the projection coordinate of the point $Q_i(x_i,y_i,z_i)$ on the plane is $Q_i'(x_i',y_i',z_i')$, the vector $|\overline{PQ'}|$ can be calculated. Assuming that the angle between the vector $|\overline{PQ'}|$ and the transverse coordinate positive vector S of the texture coordinate X_u is θ, the coordinates of $Q_i'(x_i',y_i',z_i')$ in the two-dimensional coordinate system can be obtained as

$$\begin{cases} S_{Q_i}=L\ \cos\ \theta,\\ T_{Q_i}=L\ \sin\ \theta, \end{cases} \tag{14}$$

where

$$L=\sqrt{(x_i'-x_o)^2+(y_i'-y_o)^2+(z_i'-z_o)^2},$$

$$\begin{cases} \cos\ \theta=\dfrac{\overline{PQ'}\cdot S}{\left|\overline{PQ'}\right|\cdot S},\\ \sin\ \theta=\left|\sqrt{1-\cos\theta^2}\right|. \end{cases} \tag{15}$$

Since, the angle is in the range $[0,\pi]$, the sinusoidal value will be negative, so the sinusoidal value must be absolute to get the correct coordinates.

Using the above calculation, every projection point in the plane can get the coordinate points in the ST coordinate system. The texture coordinate system u-v is located in the range of [0, 1]; hence, it is necessary to normalize the coordinate points. If $S_{\max}$ and $T_{\max}$ are the maximum values of S_{Q_i} and T_{Q_i}, respectively, the final texture coordinates of the fixed points of the model obtained by proportional transformation are shown using

$$\begin{cases} U_{Q_i}=\dfrac{S_{Q_i}}{S_{\max}},\\ V_{Q_i}=\dfrac{T_{Q_i}}{T_{\max}}. \end{cases} \tag{16}$$

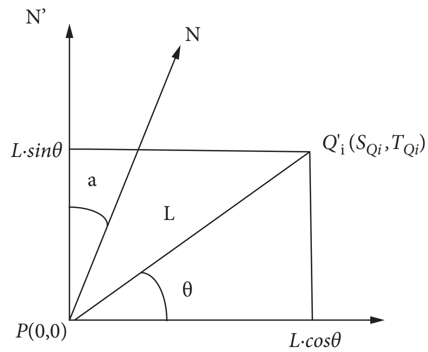

Figure 3: Schematic diagram to construct the S-T coordinate system.

The texture coordinates' system schematic is shown in Figure 4.

As shown in Figure 4, the user needs to change the mapping position, i.e., change the point P, which controls the origin of the texture mapping. It corresponds to the coordinate origin in the texture space, and the user needs to change the mapping direction, i.e., change the point M and point N, which control the direction of the texture mapping, respectively. In this figure, vectors PM and PN correspond to the u- and v-axis in the texture space, and the user needs to change the mapping size, namely, change the point M and point N, which control the size of the texture mapping.

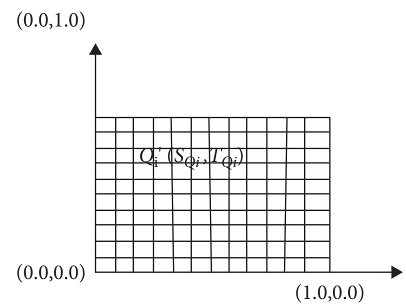

Figure 4: Texture coordinates' system.

3.4. Comparison of Changes to the Parameters. Three parameters, P, M, and N, are used to control the effect of local texture mapping in determining the coordinates of vertices. Here, P is the origin of texture mapping and corresponds to the origin of texture image in the 2D coordinate system. It controls the position of local texture mapping. The vector $\overrightarrow{PM}$ (S-axis) of point M and point P controls the direction of the u-axis of the texture image, which corresponds to the x-axis in a two-dimensional coordinate system. The change in the direction of $\overrightarrow{PM}$ also affects the axial direction of S-axis, according to its determination that results in the rotation of the texture map. By changing the size of vector $\overrightarrow{PM}$, the stretching and shrinking of texture can be achieved. Similarly, the vector $\overrightarrow{PN}$ (T-axis) of point N and point P controls the direction of the texture image axis, and the stretching and shrinking effects in the longitudinal direction can be achieved by changing its size. If the texture image is no longer required to be rotated, one can fix the S-axis in the positive direction so that the mapping direction does not change.

4. Experimental Analysis

This paper chooses Windows 10 as the experimental device, the model is CubiB171 N 8GL009BCN BN5000, the CPU memory is 6 GB, and the experimental platform is MATLAB9.0, and this paper takes Figure 5(a) as the experimental object, takes the visual communication effect as the foundation, and uses the designed method to render and analyze the system performance.

In order to verify the performance of this system, the images rendered in this system are compared with the images rendered in Linux graphics rendering system [6] and fluid cloud simulation rendering system [7]. The comparison results are shown in Figure 5.

As can be seen from Figure 5 and 5(b) is a picture rendered through the methodology proposed by this paper. Figure 5(c) is an image rendered by the Linux graphics rendering system [6] which has color differences, many color stripes, and serious distortion. Figure 5(d) is an image rendered through the fluid cloud simulation rendering system, on which many noise spots appear, resulting in blurred image rendering, which cannot be accurately displayed, resulting in a part of the chromatic aberration and a lower effect than that of the Linux graphics rendering system. Figure 5(b) is the poster image after the system rendering. It can be seen from the image that, after the system rendering, the poster image is clear, there is no noise interference, the color difference is rectified by the filter, and the color is more real. Compared with the other two kinds of rendering systems, this system has better rendering effect on the poster image and has excellent rendering effect.

When the system is rendering, it will be affected by factors, such as operation wait time. Compared with the other two systems, the result is shown in Table 1.

As can be seen from Table 1, the waiting time of all rendering operations in this system is not more than 0.5 s, followed by fluid cloud simulation rendering system, the maximum waiting time is 0.90 s, the system with the longest waiting time is the Linux graphics rendering system, and the maximum waiting time is 1.12 s. The average waiting time of

(a) (b) (c) (d)

Figure 5: Render contrast effect. (a) Original image. (b) Images rendered by this paper. (c) Images rendered by [6]. (d) Images rendered by [7].

Table 1: Render operation waiting time.

Rendering operation	System waiting time in this paper	Linux graphics rendering system waiting time	Liquid cloud simulation rendering system waiting time
Image rendering exchange waiting	0.13	0.53	0.42
Hardware submission waiting	0.24	0.80	0.63
Image rendering processing waiting	0.15	0.77	0.54
Image data waiting	0.31	1.12	0.90
Image buffer waiting	0.15	0.43	0.27
Wait for completion	0.28	0.76	0.67
Average value	0.18	0.67	0.53

the system is 0.18 s, which is better than that of the Linux graphics rendering system and the fluid cloud simulation rendering system. It proves that the system has the best performance, and the poster image is better.

After image processing, the pixel change is affected by image size change. Comparing the pixel change of the system and other two systems in different image sizes, the result is shown in Figure 6.

Figure 6 shows that no matter how the size of the poster image changes, the poster image rendered by this system keeps a stable pixel, while the image pixel change of the Linux graphics rendering system and the fluid cloud simulation rendering system fluctuates greatly, and there is no obvious trend change, which shows that the image pixel change of these two systems does not vary according to the image size, and at the same time, it indicates that the rendering effect of these two systems is extremely unstable. Compared with other systems, the rendering effect of this system is more stable, and the rendered poster image is more effective.

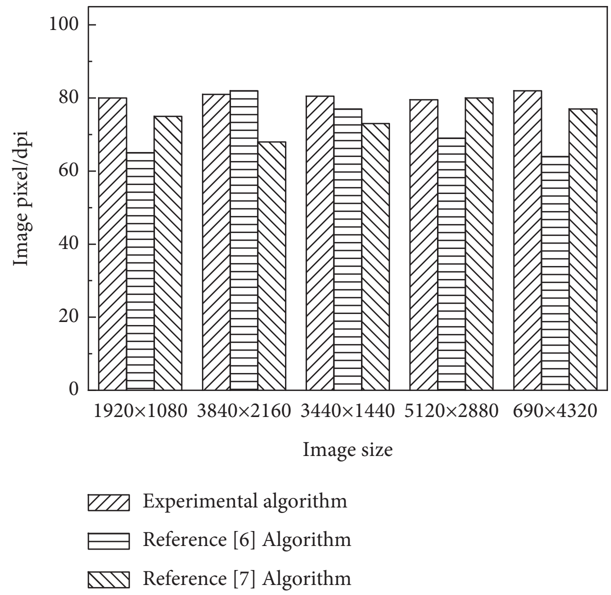

Figure 6: Image rendering effects of different sizes.

5. Conclusions

In this paper, an artistic aided design method based on scene vision comprehension algorithm is proposed. The proposed approach can effectively extract the known scene image information, detect the salient region texture features of the collected color multitexture images by super-resolution fusion method, and identify the 2D texture features according to the texture and color feature components of the color multitexture image. The proposed approach is helpful to solve the problem of unclear output image, improve the output quality of the images, and improve the visual effect of artistic aided design. To verify the efficiency of this approach, a comparison is made with the images rendered in Linux graphics and fluid cloud rendering. Simulation results show that the proposed method is more accurate than the existing methods for extracting the information of known images, which helps to solve the problem of clearly visible output images and improves the overall design effect.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that he has no conflicts of interest.

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Retraction

Retracted: Research on Analysis and Classification of Vulnerability of Electromagnetic Pulse with a STM32 Single-Chip Microcomputer

Scientific Programming

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Scientific Programming has retracted the article titled "Research on Analysis and Classification of Vulnerability of Electromagnetic Pulse with a STM32 Single-Chip Microcomputer" [1], due to concerns with the authenticity of the data. It was found that previous versions of this submission contained a figure unrelated to the topic of the paper and this graph was subsequently identified within several other submissions, all with accompanying text claiming to have generated the graph. A number of these submissions were rejected from the journal; however, 6 were published and have now been retracted from *Security and Communication Networks* and *Scientific Programming* [2–6].

The authors responded to explain that an author from one of the identified submissions had provided copy editing for their manuscript and introduced the graph and accompanying text in error.

The authors were unable to provide copies of correspondence to support their claim or the raw data from their study. The authors' explanation did not satisfy the concerns of the editorial board, and the article is therefore being retracted due to concerns with the reliability of the data.

The authors do not agree to the retraction.

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Research Article

Research on Analysis and Classification of Vulnerability of Electromagnetic Pulse with a STM32 Single-Chip Microcomputer

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With the continuous development of information technology, the performance of the entire traditional electrical system is gradually optimized. Nowadays, the single-chip technology is an important part of the traditional electrical system because it determines the operating quality of the entire traditional system. However, due to the electromagnetic pulse, the single-chip microcomputer system may be interfered with malfunction or damage, which seriously affects its performance. Therefore, to investigate the impact of an electromagnetic pulse on a single-chip microcomputer system, in this research work, we have used a STM32 single-chip microcomputer as the research object by setting up multiple sets of STM32 single-chip microcomputer serial communication systems. Besides, we have conducted an electromagnetic pulse vulnerability experiment using the inductive coupling inject method which has improved the antielectromagnetic pulse capacity of the STM32 single-chip serial communication system. The experimental results show that the damage threshold of the single-chip microcomputer with positive pulse injection is greater than the negative pulse injection, which indicates that the serial communication system of the STM32 single-chip microcomputer is more sensitive to the negative pulse injection. Moreover, this research work is of great significance to evaluate more accurately the viability and anti-interference capability of a single-chip microcomputer system under the action of electromagnetic pulse.

1. Introduction

Modern electronic systems must be highly resistant to a variety of electromagnetic interruptions to avoid faults that could have unintended repercussions if the system's functionality is important to security [1]. As a result, understanding the system's immunity is crucial. An electromagnetic pulse (EMP) is a high-frequency transient burst of electromagnetic energy that generates a significant electric field due to the rapid acceleration of energetic particles, either naturally or artificially produced. Lightning is a natural form of EMP that occurs when the atmosphere is filled with excessively charged particles, whereas an EMP generator is used to produce a constructed or intentional electromagnetic pulse. Electromagnetic pulse energy frequencies range from zero hertz to gigahertz (GHz) [2] and can be communicated by a magnetic field, electrical field, electrical conduction, and electromagnetic conduction, based on the variety of the pulse. On the other hand, STM32 single-chip microcomputer refers to the 32 bit microcomputer developed by STMicroelectronics in recent years. It has been widely used in automatic navigation system, intelligent communication equipment, and other fields by its diversified functional structure, high-cost performance, and easy-to-use operation mode. Electromagnetic pulse is everywhere, with the high integration of single-chip microcomputer systems; electromagnetic pulse has posed a dangerous threat to single-chip microcomputer systems. On the one hand, an electromagnetic pulse can make the chip of a single-chip microcomputer system produce logical chaos, leading to the system abnormal or failure, causing soft damage. On the other hand, an electromagnetic pulse can cause logical chaos in the chip of a single-chip microcomputer system by causing soft damage, while, on the contrary, an electromagnetic pulse can damage or burn the components and microelectronic circuits of a single-chip microcomputer system, causing hardware damage, so it is important to study the subject. Since the beginning of this century, domestic researchers have carried out a lot of work [3–5] on the effect and vulnerability of electromagnetic pulse to single-chip microcomputer systems and analyzed the reasons of various effect phenomena to some extent. However, the existing research is mainly to classify single-chip microcomputer systems whether there is damage or not and does not classify the vulnerability levels for various effect phenomena. Moreover, due to high test costs and limited data, it is impossible to determine the statistical law of vulnerability for various effect phenomena.

Inspired from the work of the above, this paper used the same batch of STM32 single-chip microcomputers with the following contributions:

(i) To conduct an electromagnetic pulse vulnerability experiment by inductive coupling injection.
(ii) To investigate/analyze the level of electromagnetic pulse vulnerability.
(iii) To carry out the electromagnetic pulse vulnerability experiment of STM32 single-chip microcomputer under the condition of pulse current inductive coupling injection.
(iv) To explore the influence of different factors on vulnerability experiments, we have set up a variety of control groups.
(v) To improve the antielectromagnetic pulse capacity of the STM32 single-chip serial communication system, we have used a shielded line as the serial communication line.
(vi) To investigate the sensitivity of the serial communication system of STM32 single-chip microcomputer, either it is more sensitive to the negative pulse injection or not.

The rest of the paper is organized as follows. Section 2 represents materials and methodology that we have adopted during our work, Section 3 shows the experimental work, and Section 4 illustrates the simulation results and experimental analysis. We conclude our paper in Section 5.

2. Materials and Methodology

In this section, we will discuss the materials and methodology employed in our suggested strategy for analyzing and classifying the vulnerability of electromagnetic pulses with an STM32 single-chip microcontroller in this part.

2.1. Materials

2.1.1. Electromagnetic Pulse (EMP). A high-concentration blast of electromagnetic energy created by the rapid speed of charged particles is known as an electromagnetic pulse (EMP). As a result of this huge EM energy, our electrical network, communication networks, and computer systems may be destroyed. A short, high-intensity pulse with a pulse width measured in nanoseconds is referred to as transient electromagnetic energy. Such pulses can be emitted as an electric or magnetic field as a result of natural or man-made causes [6].

2.1.2. Types of Electromagnetic Pulse. An EM pulse is a short-duration pulse of energy, which can be produced by a variety of sources including natural, man-made, and military weaponry. All of these sources produce pulse trains that are recurrent and regular. Types of electromagnetic pulse are shown in Figure 1.

(1) *Natural EM Pulse*. LEMP (lightning electromagnetic pulse) is the most common natural source of EM radiation. LEMP can generate massive currents of a few mega-amps, which can cause injury in man-made electronic circuits and electronic systems [5]. ESD is another natural EM source. Interaction and separation of 2 charged objects cause electrostatic discharge (ESD). By sending a high voltage pulse into an electrical circuit, ESD can cause damage [7, 8].
(2) *Man-Made EM Pulse*. Man-made EM radiation is much more detrimental to our health than natural EM radiation. Cooking appliances, televisions, radios, cell phones, and electrical power connections are all sources of man-made electromagnetic radiation. A train of pulses can be generated by the switching action of digital electronic circuitry as well as the internal electrical contact spinning of electrical motors [9]. Electric power lines carry many kilovolts of power, which is powerful enough to kill electronic devices and circuits that are not safeguarded sufficiently.
(3) *Military EM Pulse*. A nuclear detonation in the atmosphere releases gamma rays from the nuclear reaction with a rising time of nanoseconds, resulting in a nuclear electromagnetic pulse (NEMP) [10–12]. These gamma rays cause a flux of Compton scattering returning electrons in the atmosphere, resulting in an electric current concentration. This pulse or EM radiation can have an impact on our electrical system, as well as the sea and air. Nuclear EMPs are categorized into three parts E1, E2, and E3. E1 is the quickest of all electromagnetic elements, with temporal durations ranging from microseconds to nanoseconds. E1 is a powerful electric field capable of rapidly producing an exceptionally high voltage in electrical conductors, destroying our electrical system, computers, and communication devices. The E2 component of an electromagnetic pulse is slower than the E1 part. E2 elements have properties that are identical to lightning electromagnetic pulses, making them the easiest to defend against. Across all electromagnetic components, the E3 element is the slowest [13–16]. The Sun produces this type of pulse.

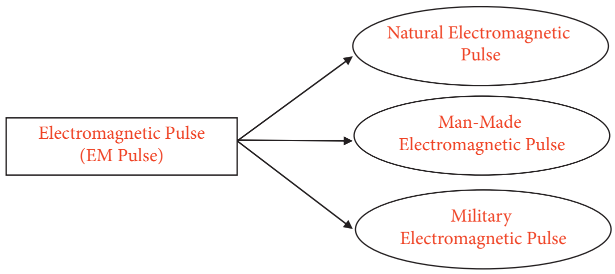


Figure 1: Types of electromagnetic pulse.

2.1.3. Effect of EMP on Electronic Circuits. An EMP (electromagnetic pulse) is a burst of energy that damages electronic circuits. EM weapons can generate a pulse of energy, which can destroy electronic systems. There are two sorts of coupling modes that can occur:

(i) Front door coupling: EMP interacts with a front-end digital equipment such as antennas in this type of coupling and destroys semiconductor devices in transmission lines such as receivers and transmitters [17].

(ii) Back door coupling: back door coupling occurs when an EMP interacts with back-end electronic apparatus via data, wire, and power connections, causing damage to transmission devices such as power supply, data transmitters, and receivers.

Any electromagnetic pulse's primary target is semiconductor devices. Breakdown happens in BJT devices when the junction is reverse biased as a result of the EM pulse. Thermal damage to the PN junction is another impact of the EM pulse. The EM pulse causes very strong electric fields to gust through the gate dielectric in field-effect transistors devices like MOSFET. The waveform of a mixture of pulses depicts how the electromagnetic field's intensity or current changes over time. Pulses have a strong leading edge and rapidly reach their maximum level [18]. EMP energy passes through the cables and circuitry of electronic equipment. In sophisticated systems with more wiring, energy is gathered more efficiently. In a matter of nanoseconds, the EMP blasts up to 50,000 volts of energy into electrical circuits [19]. This pulse completely melts modern computer CPUs.

2.1.4. STM32 Single-Chip Microcomputer. STM32 is a STMicroelectronics series of 32 bit microcontroller integrated circuits. Each microcontroller has a processing core, static RAM, flash memory, a debugging connection, and different peripherals on the inside [20]. The STM32 microprocessor group comprises 14 series, each of which is based on an ARM Cortex-M7F, Cortex-M4F, Cortex-M33, Cortex-M3, Cortex-M0+, or Cortex-M0 processing core. Abstractly, the Cortex-M4F is a Cortex-M3 with DSP and single-precision floating-point instructions [21, 22].

2.2. Methodology

2.2.1. Hardware Circuit. The power supply component, the main control part, and the communication part are the three main problems of the control system's hardware circuit [18]. Through the USB charger, the main supply component (220v) is connected to the USB port. The suggested system's main control element is in charge of the tiny microcomputer's control signal. STM32F103RCT6 Chip and STM32F103RCT6 Chip are linked via USB ports. Serial port communication is used in the communication component, which connects the USART serial port to RS232.

To conduct an electromagnetic pulse vulnerability experiment, we have selected the same batch of two STM32 microcomputers to build a set of serial communication systems. The microcomputer without an LCD (liquid crystal display) is used as the sending end and its TX pin circularly sends 8 bit binary data 00000000 to 11111111. The microcomputer with an LCD is used as the receiving end, where the data are received by its RX pin. This data will be displayed on the 2.8-inch LCD in a cycle from 0 to 255 decimal data. This system is mainly composed of an STM32-F103MINI microcomputer, STM32F103RCT6 chip, 2.8-inch LCD, USB charger, and data line (serial communication line and ground electrode), as shown in Figure 2.

2.2.2. Vulnerability. Vulnerability is a flaw in a computing device used by an attacker, such as a hacker, to break privilege boundaries. An attacker must have at least one tool or technique, which can connect to a system flaw to exploit the vulnerability. Vulnerabilities are sometimes referred to as security vulnerabilities in this context. Computer security vulnerabilities can broadly be divided into the following 4 categories [23]:

(i) *Network Vulnerabilities.* These are flaws in a network's software or hardware that make it vulnerable to outside infiltration. Examples are Wi-Fi gateways that are not secure and firewalls that are not set up properly.

(ii) *Operating System Vulnerabilities.* These are flaws in a specific operating system that hackers can use to obtain entry to or destroy an asset that the OS is installed on. Examples are default super user accounts, which may exist in some OS installations and hidden backdoor applications.

(iii) *Human Vulnerabilities.* The human factor is the weakest link in so many cyber-security systems. User errors can readily expose sensitive data, provide hackers with exploitable entry points, or cause systems to malfunction.

(iv) *Process Vulnerabilities.* Process design constraints can cause some vulnerability. The usage of weak passwords is an example of this kind of vulnerability.

Major types of vulnerabilities are shown in Figure 3.

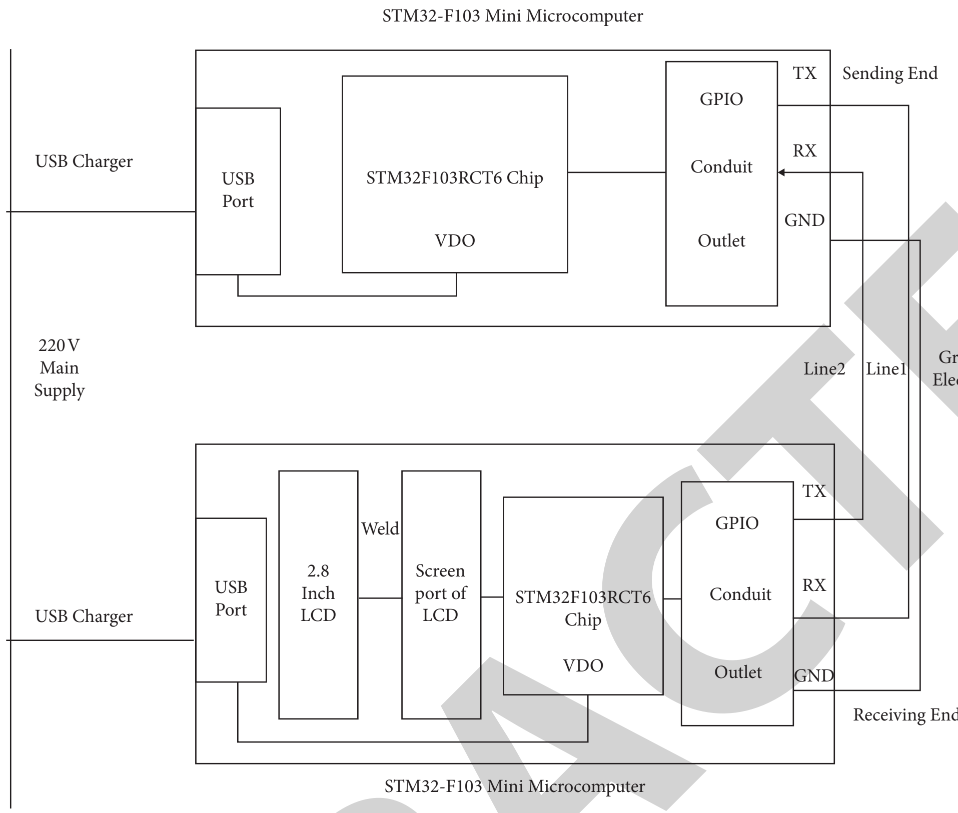


Figure 2: Composition of the serial communication system.

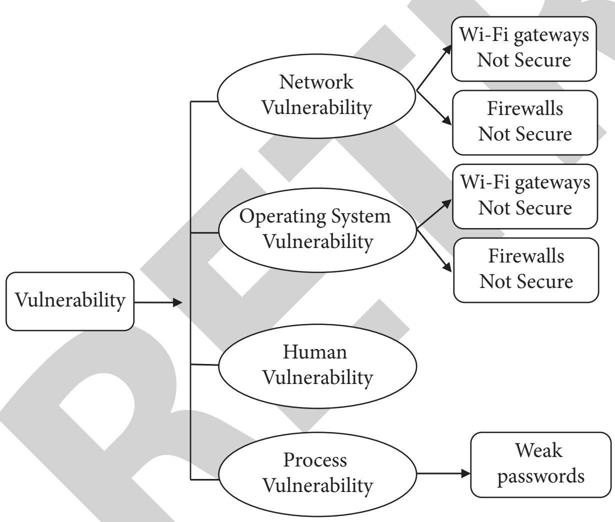


Figure 3: Major types of vulnerabilities.

2.2.3. Levels of Vulnerability. The effect of injection pulse current of different intensities on STM32 microcomputers is varied. We have combined the results of the electromagnetic pulse vulnerability experiment of the STM32 single-chip microcomputer to check whether the working state of the STM32 single-chip microcomputer is normal and serial communication function is changed [24]. This paper divided the experiment phenomena into three vulnerability levels of interference, failure, and damage, as shown in Figure 4 to analyze the vulnerability reasons:

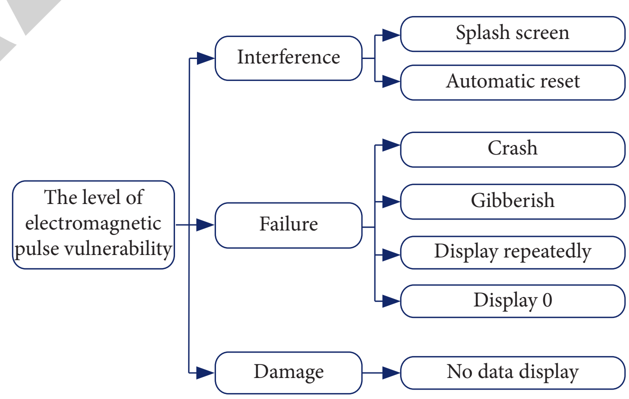


Figure 4: The level of electromagnetic pulse vulnerability.

(1) Interference: under the action of pulse current injection, the serial communication of the STM32 single-chip microcomputer failed to work properly within a short period. However, the serial communication returned to normal by itself after pulse current injection, and such a short-time disorder did not affect the normal working function of serial communication. Therefore, the STM32 single-chip microcomputer is said to be "interference" under the injected energy intensity.

(2) Failure: under the action of pulse current injection, the serial communication of STM32 single-chip microcomputer could not work normally, but the working state could be restored after manual button

reset or repowering; then, the STM32 single-chip microcomputer is said to be "failure" under the injected energy intensity.

(3) Damage: under the action of pulse current injection, the serial communication of STM32 single-chip microcomputer stopped working, and it still stopped working after manual button reset and repowering. Only replacing the new STM32 single-chip microcomputer or serial communication pin can restore its normal working function, and then the STM32 single-chip microcomputer is said to be "damage" under the injected energy intensity [25].

3. Experimental Work and Results

In this section, we discuss our experimental work for our proposed scheme and then explain its results in detail.

3.1. Conditions of the Experiment. The electromagnetic pulse vulnerability experiment of the STM32 single-chip microcomputer is carried out under the condition of pulse current inductive coupling injection. The INS4040 high-frequency noise generator, 9142-1N current injection probe, 9123-1N current monitoring probe, 30 dB pulse attenuator, and Agilent oscilloscope are the major components of the current injection equipment, which can generate square wave pulses with amplitude values of 0.01–4 kV. The square wave pulse is injected into the data line via inductive coupling using calibrated 9142-1N current injection probe, and the 9123-1N current monitoring probe is used to monitor the pulse current on the data line in real-time and is connected to the Agilent oscilloscope through the pulse attenuator, as shown in Figure 5.

In the experiment, when the experiment conditions remain unchanged and the injection pulse amplitudes are all 400 V, the inductive coupling injection is carried out for different data line combinations in turn. The typical pulse waveform observed on the Agilent oscilloscope is shown in Figure 6.

3.2. Results of Experimental Work. According to GJB548B-2005 Test Methods and Procedures for Microelectronic Device [26], the stepwise method was adopted. First, the pulse width was kept unchanged. Then, the single injection was carried out from 0.1 kV with the step value of 0.01 kV in turn. In order to prevent the cumulative effect which could cause errors in the experiment results, the time interval of each injection should be greater than 15 s [27]. Finally, since STM32 single-chip microcomputer has realized serial communication normally, the amplitude of injected pulse was recorded when the experiment phenomena occurred every time and stopped the experiment until the STM32 single-chip microcomputer could not work normally by the ways of manual button reset and repowering. If the serial communication of STM32 microcomputer stopped working when the pulse current was injected for the first time, it was judged that the experimental data were invalid [28]. It was necessary to check whether the STM32 microcomputer was in a normal state and replace the STM32 microcomputer to start the experiment again [29].

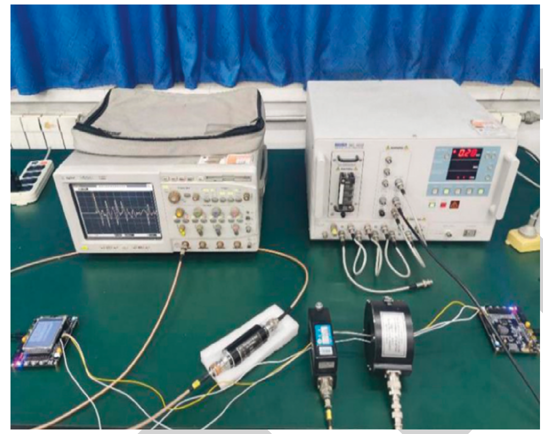


FIGURE 5: Layout of experiment equipment.

Through the experiment, it could be found that different experiment conditions and different batches of STM32 microcomputer could obtain different experiment phenomena and threshold data which reach these phenomena. The experiment phenomena of electromagnetic pulse vulnerability of STM32 microcomputer were as follows:

(1) After the pulse current was injected, the serial communication could be restored to normal by itself; the LCD screen would cause the phenomena of splash screen and automatic reset.

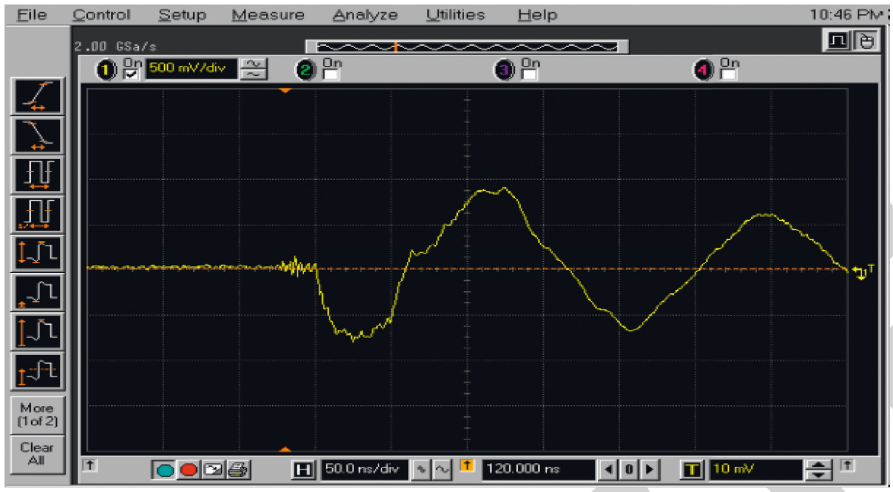
(2) After the pulse current was injected, the serial communication could be restored to normal only by manual button reset or repowering; the LCD screen would cause the phenomena of crash, gibberish, display repeatedly, and display 0.

(3) After the pulse current was injected, the serial communication still stopped working by manual button reset and repowering; the LCD screen would cause the phenomenon of no data display.

Several control groups were set up to explore the influence of injection mode, materials of serial communication lines, and injection location and injection polarity on vulnerability experiment phenomena and threshold data. Under the condition that other factors remained unchanged, the injection mode could be divided into six situations as injecting serial communication line 1, injecting serial communication line 2 and so on; the materials of serial communication lines could be divided into shielded line, unshielded line, and DuPont line; the injection location was respectively set at 25 cm, 50 cm, and 75 cm from the sending end; and the injection polarity could be divided into positive pulse injection and negative pulse injection. Twenty sample sizes were selected for each condition, and the experimental results are shown in Tables 1–4.

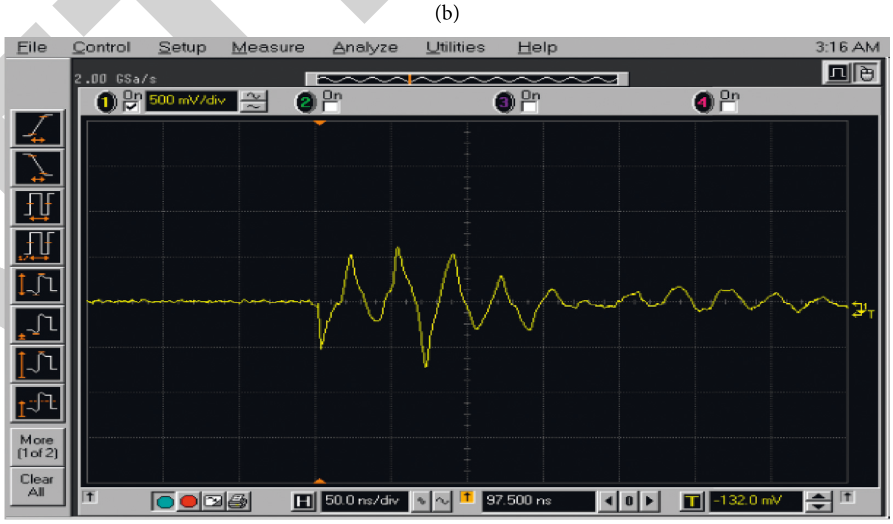
4. Analysis of Vulnerability

Electromagnetic vulnerability refers to the characteristic that the system, equipment, or device degrades the performance or fails to complete the specified task under the influence of



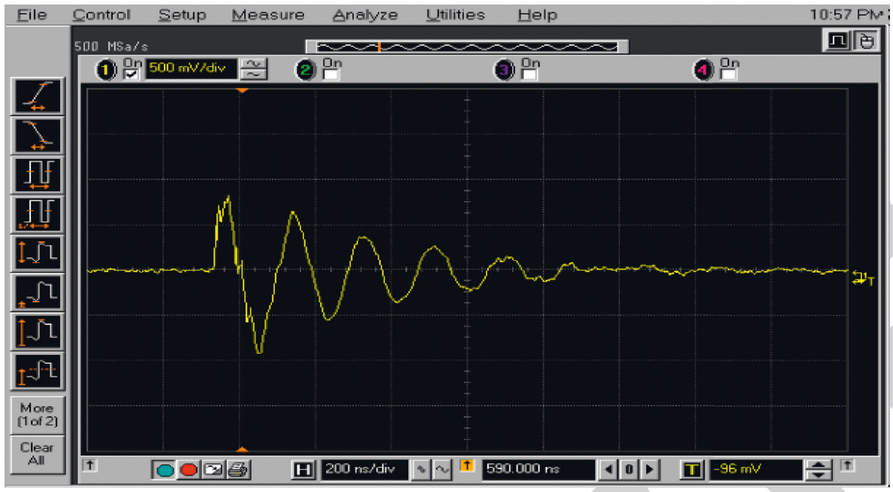
(a)

(b)



(c)

Figure 6: Continued.



(d)

Figure 6: Typical pulse waveform after inductive coupling injection. (a) Injection of single serial communication line. (b) Injection of two serial communication lines. (c) Injection of single serial communication line and ground electrode. (d) Injection of two serial communication lines and ground electrode.

Table 1: Influence of injection mode on experiment results (kV).

Experiment phenomena	Line 1	Line 2	Lines 1 and 2	Line 1 and ground	Line 2 and ground	Lines 1 and 2 and ground
No	0.10–0.31	0.10–0.28	0.10–0.18	0.10–0.20	0.10–0.15	0.10–2.00
Splash	0.32–0.79	0.29–0.46	0.19–0.31	0.21–0.45	0.16–0.30	*
Reset	*	*	0.32–0.42	*	0.31–0.40	*
Repeat	*	*	0.43–0.62	*	0.41–0.53	2.01–2.67
Display 0	0.80–1.26	*	0.63–0.73	0.46–0.78	0.54–0.63	2.68–3.32
Gibberish	*	0.47–0.53	*	*	*	*
No display	1.27	0.54	0.74	0.79	0.64	3.33

Table 2: Influence of the materials of serial communication lines on experiment results (kV).

Experiment phenomena	Shielded line	Unshielded line	DuPont line
No	*	0.10–1.69	0.10–2.00
Repeat	*	*	2.01–2.67
Display 0	*	1.70–2.59	2.68–3.32
Gibberish	*	2.60–3.20	*
No display	*	3.21	3.33

Table 3: Influence of injection location on experiment results (kV).

Experiment phenomena	25 cm	50 cm	75 cm
No	0.10–0.57	0.10–0.41	0.10–0.42
Repeat	*	0.42–0.79	*
Display 0	*	*	0.43–0.78
Gibberish	0.58–0.78	*	*
Crash	0.79–0.83	0.80–0.83	0.79–0.82
No display	0.84	0.84	0.83

electromagnetic interference [30]. The vulnerability process of an electromagnetic pulse to an STM32 microcomputer can be divided into three stages: penetration, transmission, and damage. Electromagnetic pulse penetrates STM32 microcomputer through the long-distance by using serial communication cable. Its energy becomes large currents and

Table 4: Influence of injection polarity on experiment results (kV).

Injection mode	Line 1	Line 2	Lines 1 and 2	Line 1 and ground	Line 2 and ground	Lines 1 and 2 and ground
Positive	1.32–1.37	1.03–1.09	0.81–0.85	1.02–1.07	0.82–0.86	3.92–3.97
Negative	1.27–1.29	0.52–0.55	0.70–0.78	0.76–0.79	0.46–0.54	3.31–3.34

voltages that vary with time and space and then in the form of large current, large voltage transmission to the chip, integrated circuit, connection points, and other fragile parts inside STM32 microcomputer, making these parts damage due to high energy density.

Through the experiment, it could be found that except for the serial communication pins of the STM32F103RCT6 chip were damaged; other pins or devices were not damaged. Because the STM32F103RCT6 chip had five groups of serial communication pins, as long as a set of serial communication pins was replaced, serial communication could be continued after burning the program. However, if all of them have been damaged, a new set of STM32 microcomputer serial communication systems should be built for the experiment. Combined with the results of the electromagnetic pulse vulnerability experiment of STM32 single-chip microcomputer, the reasons for vulnerability caused by various experimental phenomena were analyzed:

(1) Splash screen: the coupling current entered into the chip through the GPIO conduit outlet and then reached the 2.8-inch LCD through the screen port of LCD. As a result, the power supply voltage of the 2.8-inch LCD changed instantaneously, which caused the splash screen phenomenon to occur on the 2.8-inch LCD. After the pulse current, the 2.8-inch LCD automatically returned to normal.

(2) Automatic reset: the coupling current entered into the chip through the GPIO conduit outlet, electromagnetic interference appeared on the chip reset pin (NRST), and the interference signal was mistaken for the reset signal, which caused the automatic reset phenomenon to occur on the 2.8-inch LCD. After the pulse current, the 2.8-inch LCD automatically returned to normal.

(3) Crash: the serial data register (USART-DR) was confused by the coupling current and decided to enter into the chip through the GPIO conduit outlet. This caused the last half of the previous data to be executed as the same bit of data as the first half of the next data, resulting in a dead cycle [31], which caused the crash phenomenon on the 2.8-inch LCD. After manually pushing the reset or repowering the device, it would return to normal.

(4) Gibberish: the coupling current entered into the chip through the GPIO conduit outlet and the data contents in the serial data register (USART-DR) would be flipped over so the data become disordered and cause the gibberish phenomenon to occur on the 2.8-inch LCD. It would be restored to normal after manually pressing the button to reset or repowering.

(5) Display repeatedly: the coupling current entered into the chip through the GPIO conduit outlet, the transmission completion bit (TC) of the serial status register (USART-SR) was changed from 1 to 0, and the serial communication program was always in the state of waiting for the completion of transmission, resulting in the interruption of data sending and receiving and causing the display repeated phenomenon to occur on the 2.8-inch LCD. It would be restored to normal after manually pressing the button to reset or repowering.

(6) Display 0: the coupling current entered into the chip through the GPIO conduit outlet, the send break (SBK) of the serial control register (USART-CR1) was changed from 0 to 1, and then the disconnected character was sent. This character was 8 bit low level 00000000, which deemed to receive all zeros in one cycle. Therefore, the display 0 phenomenon occurred on the 2.8-inch LCD. It would be restored to normal after manually pressing the button to reset or repowering.

(7) No data display: the coupling current reached the metal pin of the chip through the GPIO conduit outlet; the metal itself would produce joule heat, especially when the metal was relatively narrow and the temperature was higher. When the temperature rose above the melting point of the metal, the metal pin would overheat and burn out [32] and cause the open circuit between the serial communication pin and the internal lead. Therefore, the serial communication stopped working, and the no-data-display phenomenon occurred on the 2.8-inch LCD. It still stopped working after manually pressing the button to reset and repowering.

According to the three vulnerability levels of interference, failure, and damage, combined with the vulnerability experiment results of the STM32 single-chip microcomputer in Tables 1–4, the threshold range of each vulnerability level is given in these tables. We adopted the Bayesian statistical method and OpenBUGS software based on the Markov chain Monte Carlo method to carry out Gibbs sampling and fitting analysis on the threshold data, and posterior mean value and posterior standard deviation of each vulnerability level were obtained, as shown in Table 5.

Finally, we have obtained the probability of each vulnerability level of STM32 single-chip microcomputer under the action of certain injected energy by using Origin software; the results are shown as in Figure 7.

Table 5: Parameter estimation results of vulnerability level.

Vulnerability level	Range of threshold	Posterior mean value	Posterior standard deviation
Interference	0.16–0.79 kV	0.79	0.35
Failure	0.41–1.26 kV	1.26	0.45
Damage	0.54 kV	1.57	0.54

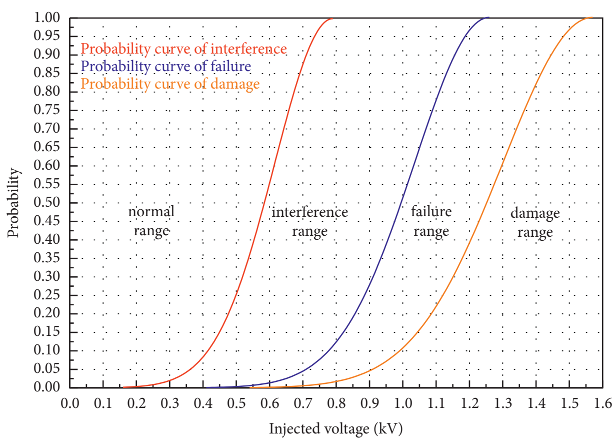


Figure 7: Probability curve of vulnerability level.

5. Conclusions

This research study has investigated the impact of an electromagnetic pulse on a single-chip microcomputer system using the STM32 single-chip microcomputer as the research object. Besides, this work has conducted an electromagnetic pulse vulnerability experiment by using the pulse current injection device of the author's work unit and the inductive coupling injection method, where a variety of control groups were set up to explore the influence of different factors on vulnerability experiment. The results showed that the threshold data of serial communication line 1 were greater than serial communication line 2 and the threshold data of common-mode injection were greater than differential mode injection, which indicated that serial communication line 2 and differential mode injection were more sensitive to pulse current. To improve the anti-electromagnetic pulse capability of the STM32 single-chip microcomputer during serial communication system, the shielded line should be used as the serial communication line. The damage threshold of the single-chip microcomputer with positive pulse injection was greater than the negative pulse injection, which indicated that the serial communication system of the STM32 single-chip microcomputer was more sensitive to the negative pulse injection.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

Applications of Deep Learning in News Text Classification

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The advancement in technology is taking place with an accelerating pace across the globe. With the increasing expansion and technological advancement, a vast volume of text data are generated everyday, in the form of social media platform, websites, company data, healthcare data, and news. Indeed, it is a difficult task to extract intriguing patterns from the text data, such as opinions, summaries, and facts, having varying length. Because of the problems of the length of text data and the difficulty of feature value extraction in news, this paper proposes a news text classification method based on the combination of deep learning (DL) algorithms. In order to classify the text data, the earlier approaches use a single word vector to express text information and only the information of the relationship between words were considered, but the relationship between words and categories was ignored which indeed is an important factor for the classification of news text. This paper follows the idea of a customized algorithm which is the combination of DL algorithms such as CNN, LSTM, and MLP and proposes a customized DCLSTM-MLP model for the classification of news text data. The proposed model is expressed in parallel with word vector and word dispersion. The relationship among words is represented by the word vector as an input of the CNN module, and the relationship between words and categories is represented by a discrete vector as an input of the MLP module in order to realize comprehensive learning of spatial feature information, time-series feature information, and relationship between words and categories of news text. To check the stability and performance of the proposed method, multiple experiments were performed. The experimental results showed that the proposed method solves the problems of text length, difficulty of feature extraction in the news text, and classification of news text in an effective way and attained better accuracy, recall rate, and comprehensive value as compared to the other models.

1. Introduction

News has evolved into an institution that disseminates the most up-to-date information to the public. News is disseminated through a variety of channels, including online media, newspapers, television, radio, and other forms of media. In general, news supplied through the media is divided into numerous areas, including health, economics, politics, and sports. Furthermore, at the moment, news is still manually classified into these categories, which means that when submitting a news item, the submitter would first know the entire text of the news to be published, which is then placed in the appropriate category. This is indeed a very tough task for the news unloaders who have a high amount of news items to deal with. As a result, an intelligent system that can automatically identify content according to existing news category is required to assist news uploading personnel when posting such data. A machine learning strategy that can elucidate these issues is needed to solve these issues and is able to identify the news content types.

Text categorization is a fundamental task in the field of natural language processing (NLP) and is frequently utilized in the retrieval of information, unreliable analysis and identification, analysis of emotions, identification of spam emails, etc. [1–4]. Text mining is a term used to describe the method of extracting patterns or knowledge from unstructured texts. This can be thought of as a data mining or knowledge discovery extension from a structured (character and word) dataset. Text has evolved into one of the most fundamental forms of data storage; text mining is thought to have a greater market viability than data mining. From the recent research studies, it is observed that about 80–85% of information of the companies and organizations are presented and stored in the textual format. Text mining, on the contrary, includes a significant number of more complex jobs (in comparison to data mining) because it deals with text data that is inherently unstructured and unclear. Information extraction, text analysis, information retrieval, and categorization are all part of the multidisciplinary discipline of text mining. Text mining technique is used as one of the method for the classification of news text [5]. Furthermore, one of the important functionality of text mining is that it identifies the most important patterns in a large amount of text dataset. It is also used for clustering, feature extraction, and information retrieval.

Researchers are interested in NLP applications such as text categorization, machine translation, speech recognition, document summarization, and question answering because of the vast amount of data available online. As a result, research in the NLP sector has progressed, and numerous state-of-the-art models in ML and AI have been developed [6]. Text classification has various applications such as e-commerce platform, blogs, content curator, directories, and news agency documents and text classification [7]. It is a supervised ML technique that uses text documents along with its labels for training the classification models. It can be done at several levels, including sentence, aspect, and document levels. In addition, extracting useful information/features from the sentences can be used to perform the sentiment analysis [8].

In the field of text classification by using deep learning (DL) approaches, researchers at home and abroad have made a lot of exploration. Yinghua et al. [9] proposed a model for the English text classification that extracts the local features by the CNN after the text input matrix is constructed by the word vector model, and the result index of text classification is improved. Tianlong et al. [10] proposed a dynamic CNN model in which they improved the pooling layer of the CNN and retained the semantic order after the pooling layer. In other studies, in order to highlight and extract the most important features from the textual data, the researchers have added an attention mechanism to the CNN model [11, 12]. The experimental results show that the most important features are preserved selectively which improved the text classification result significantly. Jinyuan et al. [13] have used a CNN model to analyze the emotion of twitter text, which solves the problem that the existing emotional classification methods are difficult to excavate the deep semantic features in the text. Ya and Shuang [14] constructed a word vector matrix through TF, IDF, and word2vec and highlighted the important word information in the text.

Yumin et al. [15] used a CNN model to solve the problem of web text classification that reduced the complexity of the model. In other studies conducted by different researchers [16–18], word2vec has been used to construct a word vector matrix for new product reviews and then the emotions are classified using textual data.

However, the abovementioned research of combination depth learning uses a single word vector to express text information and only the information of the relationship between words is considered, but the relationship between words and categories is ignored which indeed is an important factor for the classification of news text. The following are some of the basic contributions of this paper:

(i) This study follows the research idea of the combination of DL techniques based news text classification and selects CNN, LSTM, and MLP models to propose a custom MLP model of news text classification based on double input combined depth learning.

(ii) The proposed model is expressed in parallel with word vector and word dispersion. The relationship among words is represented by word vector as input of CNN module, and the relationship among words and categories is represented by a discrete vector as an input of the MLP module in order to realize comprehensive learning of spatial feature information, time-series feature information, and relationship between words and categories of news text.

(iii) Multiple experiments were conducted to check the stability and performance of the proposed method.

(iv) The experimental results show that the performance of the proposed method is way better than the other approaches in terms of prediction accuracy and other performance measures.

The rest of the paper is organized as follows. Section 2 represents the related work, while Section 3 illustrates the proposed model for news text classification. Section 4 demonstrates the experimental results and analysis, and finally, we conclude our paper in Section 5.

2. Related Work

In recent years, deep learning (DL) has become a research trend and hot spot for the research communities across the globe. DL has numerous applications in various fields such as healthcare, education, industries, agriculture, and text processing. Some scholars have used DL technology to extract text feature information. For example, the problem of data dimension explosion and high sparsity is not easy to appear when extracting text features by traditional ML algorithms. Longfeng [19] first proposed the word2vec model, which provides technical support for word vector conversion. At the same time, some scholars proposed to use neural network as a classification model, for example, Alswaidan and Menai [20] have used the word2vec model to generate word vector and then used the CNN model to learn feature information. Based on the word vector, long short-term memory (LSTM) is used to analyze public opinion emotion of emergency network in the process of studying the pre-Qin classics. First, they constructed the classification system, then expressed the text characteristics with TF-IDF, and input it into the Bi-LSTM (bi-directional LSTM) model. The experimental results show that the effect of the DL method was better than that of the ML methods. Compared to the traditional ML methods, the accuracy of the DL methods has been improved significantly.

There are several types of neural networks, and the nature and structure of each network model learning information is different and depends on the nature of the problem. For example, the CNN model is more inclined to extract local spatial feature information because of its unique local connection structure. Recurrent neural network (RNN) model is more inclined to extract the feature information of time series due to its sequence structure (the output of a certain time is part of the input of the next time). Because of the defects of the ability to extract information from a single DL model, some scholars began to study the feature information extraction of the combined DL models. For example, Mu et al. [21] introduced the attention mechanism to study the news text classification based on the combination of the DL models. Cao et al. [22] input the text features into the RCNN (region CNN) neural network model composed of RNN and CNN and applied them to text classification, and the classification performance is improved obviously. Zhao et al. [23] proposed a DL model composed of CNN and LSTM based on attention (CLA) by repeated series of convolutional layers and circulation layer. Firstly, the word coding was implemented in series; secondly, they implemented it to realize the sentence coding, and finally, the implicit emotion analysis task was realized at the last layer using the softmax function, based on attention mechanism. In the study of text classification, Ke and Chen [24], firstly, quantify the text words and then extract the text feature information by neural network and give weight to each feature by TF-IDF algorithm, and finally use the Bayesian classifier to achieve the classification task. Yu [25], discussed the principle, advantages, and disadvantages of CNN and RNN and combined a model method for searching the automatic abstract technology.

In recent years, DL-based text categorization research has made significant progress [26]. DL models, in general, excel in learning the high-level vector representations of words, phrases, and paragraphs from raw text data and have a significant impact on classification outcomes. With the advancement of DL technology, an increasing number of researchers are applying it to the field of NLP. Kim et al. [27] have used CNN to classify text and attained promising classification outcomes. However, because of the differences in expression and word structure between Chinese and English, determining the type of a Chinese text may require multiple words or characters. Keeping the variation of characters and words of both of the languages in consideration, it is mandatory to use segmentation techniques for the extraction of Chinese text. For Chinese text classification, most of the models use the segmentation techniques by segmenting the word first and then forward the segmented features the classification models to classify it [28, 29]. For the categorization of Chinese text, most of the models have used word embedding techniques [30–32]. Most contemporary Chinese text classification models, on the contrary, treat text characteristics as the fundamental unit of text representation, ignoring the useful representation of character features.

However, the abovementioned research, using DL techniques, focuses only on a single word vector to express text information. Only the information of the relationship between words is considered, but the relationship between words and categories is ignored. In order to overcome the issues mentioned above, this paper follows the research ideas of combination of DL techniques for news text classification and selects CNN, LSTM, and MLP (multilayer perception) models to propose a custom MLP model for news text classification based on double input combined DL technique. It is expressed in parallel with word vector and word dispersion, and the relationship among words is represented by word vector as an input of the CNN module. Furthermore, the relationship between words and categories is represented by a discrete vector as an input of the MLP module, to realize comprehensive learning of local spatial feature information, time-series feature information, and relationship between words and categories of news text.

3. Proposed Model for News Text Classification

This section of the paper illustrates the proposed model used to classify the news textual data. The proposed model works in different steps. When the news events appear on the Internet, the process of news text classification based on the combination of DL techniques is given as follows:

Step 1: input the text into the CNN model to predict whether the text belongs to the news event or not. If the answer/prediction is not, then it does not need to be monitored, otherwise, it enters Step 2.

Step 2 (text preprocessing and feature expression): word segmentation and filtering stop words, using the word2vec model in order to get the text word vector, and calculate the text dispersion vector. The vector input based on discreteness reflects the association information between words and categories. The greater the value is, the greater the contribution to classification is. The input based on a word vector reflects the semantic relationship between words. Using two kinds of feature expression can make the model learn the deep-seated features of the text as much as possible.

Step 3: input the word vector to MCNN (multiple CNN) modules and get the text spatial feature information through two convolution and pooling operations and then input the spatial feature to the LSTM module to learn the temporal feature information. The discrete vector is then given as an input to the MLP module, and the hidden layer neuron learns the relationship between words and categories. The output values of the MLP module and the LSTM module are spliced and fused and given as input to the softmax activation function for feature scaling and output news prediction categories.

3.1. Feature Representation among Words and Categories Based on Discreteness. When we compare the ordinary text with the news text, the news text contains relatively few keywords but has a strong relevance with the theme of the news. If "earthquake" appears in the news text, the text is likely to be earthquake event news. Therefore, this paper uses key feature words with strong correlation to express news text information and to distinguish ordinary text from event news. In DL techniques, the word vector method uses the spatial distance to represent the similarity degree of word meaning, and the one hot method uses 0 and 1 to represent whether the feature words appear or not, ignoring the proportion weight of words in the text and the association information between words and categories. The following are some of the steps that demonstrate the prescribed scenario:

Step 1: count the number of texts with specific words in a certain category to form the category frequency vector of the words. Let VIM denote the number of texts with the word I in the m^{th} category, and the frequency vector VI of the word I in the sample set with n categories is

$$V_I = (v_{I1}, v_{I2}, \ldots, v_{In}). \tag{1}$$

Step 2: considering the deviation of the class frequency vector caused by the different numbers of texts in each class, the occurrence probability of specific words in each class is calculated. Let Qi be the total number of I-type texts, and P_I be the category probability vector, which is given as follows:

$$P_I = \left(\frac{V_{I1}}{q_1}, \frac{V_{I2}}{q_2}, \ldots, \frac{V_{In}}{q_n}\right). \tag{2}$$

Step 3: calculate the variance of P_I as the dispersion of word I. The greater the variance, the greater the dispersion, indicating that the feature information contained in the classification process is more obvious. Let $\overline{p}_I$ be the probability mean of the word I and σ_I^2 be the probability variance of the word I, and the formula of dispersion is given as follows:

$$\begin{aligned} \overline{p}_I &= \frac{\sum_{i=1}^{n} v_{Ii}/q_i}{n}, \\ \sigma_I^2 &= \sum_{i=1}^{n}\left(\frac{v_{Ii}}{q_i} - \overline{p}_I\right)^2. \end{aligned} \tag{3}$$

Step 4: the text discreteness vector is composed of the discreteness of each word, while the length is the total number of words. When a word appears, the corresponding word sequence is the variance value of the word. Otherwise, it is 0. Let Z be the total number of words in the sample set and d be the text dispersion vector; then, it can be expressed as follows:

$$D = \left(\sigma_1^2, \sigma_2^2, \ldots, \sigma_z^2\right), \tag{4}$$

3.2. Proposed DCLSTM-MLP Model Structure. This section illustrates the proposed DCLSTM-MLP model and it structure. The structure of the custom-map model is shown in Figure 1.

The proposed model is mainly composed of three parts: MLP, MCNN, and LSTM. Among them, MLP takes the feature vector between words and categories based on the degree of dispersion as the input, and the hidden layer neurons learn the relationship between words and categories and output the feature information vector between words and categories. MCNN takes the word vector containing interword feature information as the input, which has five types of the convolution kernel. After the convolution pooling operation of different types of convolution kernels, it repeatedly extracts the local features of the word vector and outputs the text space feature information vector of multiple types of the convolution kernel. The feature vector extracted by one type of convolution kernel is a time segment, and the feature information extracted by multiple types of convolution kernels is composed of multiple time segments, which are given as input to the LSTM to learn the time-series feature information of multiple time segments and finally output the comprehensive spatial feature vector. The MLP and LSTM output feature vectors are spliced and fused into a new feature information vector and then given as an input to the full connection layer for re-learning. The extracted feature information after re-learning is input to the softmax layer for feature scaling, and finally, the text category is obtained.

4. Experimental Results and Analysis

This section of the paper represents the experimental results carried out via different experiments and the analysis of those results. All the experiments were performed on a laptop computer system having the specification of Intel Core-i7, 9th generation and a processor of 2.7 GHz, 12 GB of RAM, and the operating system installed on the system was Microsoft Windows 10. Anaconda, Jupyter Notebook is used as an IDE for carrying out the simulations. *Python* has been used as a language for the implementation and for generating the simulation results. The list of python packages used in this study was Pandas, Numpy, Matplotlib, Keras, Tensorflow, seaborn, and Sklearn.

4.1. Event News Text Collection. This section represents the collection of event news textual data. We divide the news events into four categories: (I) public health events, (II) social security events, (III) accidents and disasters, and (IV) natural disasters. In this study, we search 10 kinds of natural disaster events including storm disaster, rainstorm disaster, Blizzard disaster, earthquake disaster, tsunami disaster, flood disaster, debris flow disaster, forest fire disaster, sandstorm disaster, and landslide disaster and 5477 news event texts, in the form of keywords on Baidu news, using the crawler technology. We also search the open-source regular news event text set (such as economic, art, political, and other news texts), 2815 news texts, using the same technology, forming a total of 8292 news texts, which were merged.

4.2. Analysis of the Classification Model of Common Events and News Events. The total sample set contains 5477 event news texts and 2815 ordinary news texts by forming a total of 8292 sample set. From the samples' set, 6699 texts are

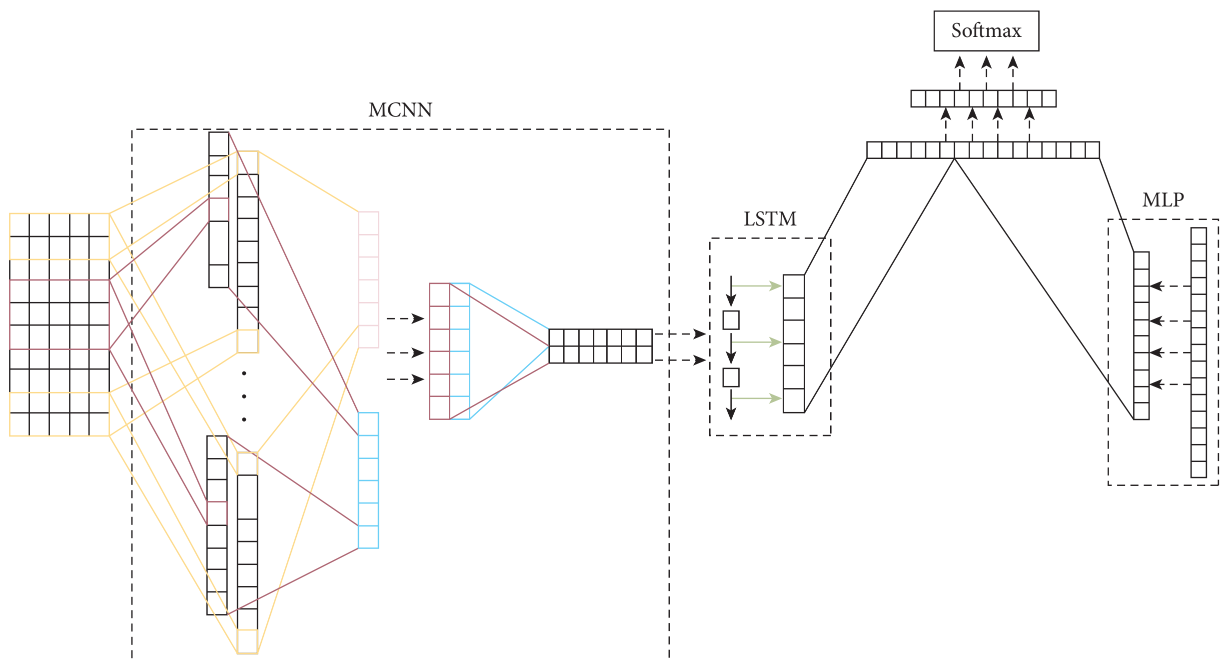

Figure 1: DCLSTM-MLP model structure.

randomly selected as the training set and 1593 texts as the test set, and the training set is input into the proposed CNN model. The main parameters of the CNN model include the first mock exam length, the word vector dimension, the number of convolution layers, and the number of neurons in the full connection layer. Each time the single model parameters are changed, and the accuracy of and recall the model and average value of the composite value are obtained by repeating the simulations 3 times. The parameters with the maximum average value are the best, and the best parameters and optimal results are shown in Table 1. Using the parameter setting mentioned in Table 1, the classification model can effectively identify ordinary text and news events and lay the foundation for the next step of news event text classification.

4.3. Analysis of News Text Based on Multiclassification Models

4.3.1. Superiority Test of Dispersion Vector. To test the feature information extraction ability of the proposed test dispersion vector expression method, the news event text is taken as the sample set and compared with the vector space model (VSM), chi-square test, and TF-IDF method. The results attained via all the mentioned techniques are shown in Figure 2. It can be seen from Figure 2 that the proposed method has better information expression ability than the VSM, chi-square test, and TF-IDF method, and the extracted feature information are more abundant and valuable for the classification model.

Based on the DL approach, the parameters of the first mock exam text classification model determine the performance of the model. To compare the DCLSTM-MLP combination model with MLP, Text-CNN, Text-LSTM, CLSTM, and CNN-MLP models proposed in this paper, we get the accuracy of each single model parameter by changing the single model parameters 3 times on the same training set of the news event text. For the average value of recall and comprehensive value, the parameter with the maximum comprehensive value is the best, as shown in Tables 1–6 .

Based on setting the best state of each model, taking the same test set of news event text as the object, the rate of accuracy, recall, and comprehensive value of each model is obtained. Table 7 shows the results of accuracy, recall, and comprehensive value of all the utilized models.

Figure 3 shows a comparative study of the performance (accuracy, recall, and comprehensive value) of all the utilized models in this study.

From Table 7 and Figure 3, we can conclude the following. In general, the more complex the structure of the text classification model is, the more is the number of neurons, the more the network level is, the stronger the learning ability is, and the stronger the comprehensive performance of the model is. From the perspective of accuracy, it can be observe that MLP < Text-LSTM < Text-CNN < CLSTM < CNN-MLP < DCLSTM-MLP. From the perspective of recall, DCLSTM-MLP > CLSTM > Text-LSTM > CNN-MLP > Text-CNN > MLP. So, in all cases, the proposed DCLSTM-MLP is better than the other models.

Compared with other neural networks, the MLP model has the simplest structure and limited ability to learn features. The structure of the CLSTM model is more complex than that of CNN-MLP, but the former uses the single input method with the word vector as the input value, while the latter uses the double input method with the word vector and the dispersion vector as the input value. The latter has more sufficient input information and more comprehensive model learning content, so the accuracy of the latter is slightly higher. The

Table 1: MLP model parameters and optimal values.

Parameter	Dispersion vector dimension	Number of neurons in the first layer	Number of neurons in the second layer
Optimum value	400	1024	256

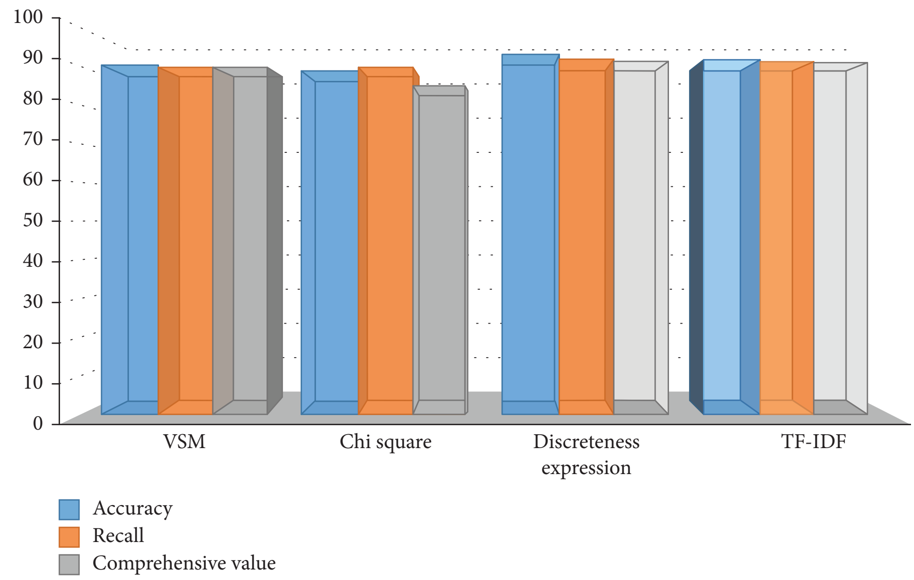

Figure 2: Performance comparison of various feature expression methods.

Table 2: CNN model parameters and optimal values.

Parameter	Sentence length	Word vector dimension	Number of convolution kernels	The number of neurons in the whole connective layer
Optimum value	80	240	512	256

Table 3: Parameters and optimal values of the text-LSTM model.

Parameter	Sentence length	Word vector dimension	Number of convolution kernels	The number of neurons in the whole connective layer
Optimum value	80	240	120	512

Table 4: CNN-MLP model parameters and best values.

Parameter	Sentence length	Word vector dimension	Number of convolution kernels	Number of neurons in the first layer	Dispersion vector dimension	Number of neurons in the second layer	The number of neurons in the whole connective layer
Optimum value	80	240	512	1024	400	256	256

Table 5: Parameters and optimal values of the CLSTM model.

Parameter	Sentence length	Word vector dimension	Number of convolution kernels	The number of neurons in the hidden layer	Number of neurons in circulatory layer
Optimum value	80	240	512	256	320

Table 6: DCLSTM-MLP model parameters and their best values.

Parameter	Sentence length	Word vector dimension	The number of neurons in the second hidden layer	The number of neurons in the whole connective layer	Number of LSTM neurons	Number of neurons in the first hidden layer	The number of convolution kernels in the first layer	The number of convolution kernels in the second layer
Optimum value	400	260	256	512	320	1024	512	256

Table 7: Accuracy, recall, and comprehensive value results of all the utilized models.

Method	Accuracy	Recall	Comprehensive value
MLP	88.76	88.25	88.05
Text-CNN	92.46	91.35	91.2
Text-LSTM	92.35	92.2	91.2
CNN-MLP	93.68	91.53	91.52
CLSTM	93	93.05	93.1
DCLSTM-MLP	94.82	94.97	94.83

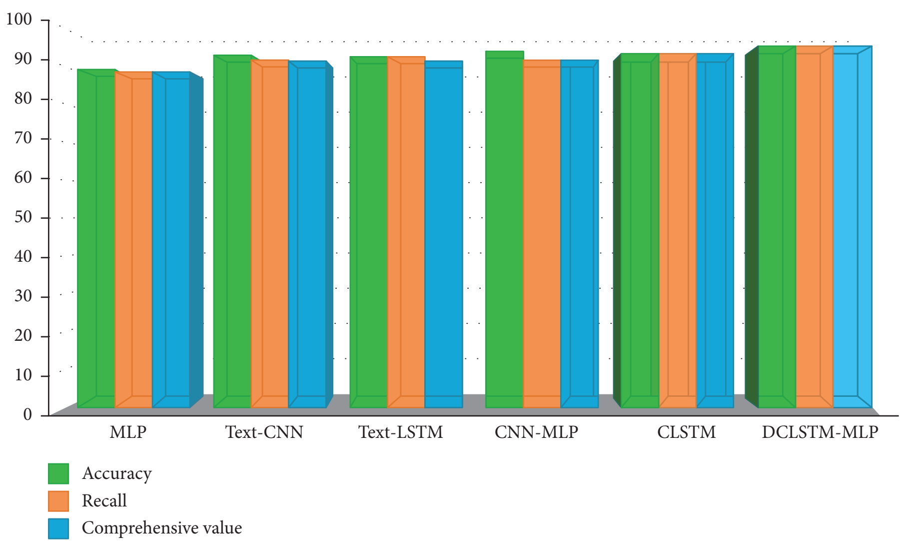

Figure 3: Comparison of the models' performance.

DCLSTM-MLP model has the most complex structure. It can learn not only the sequence information and spatial information of text but also the relationship information between feature words and categories. The accuracy of the DCLSTM-MLP model is significantly higher than the other models. The comprehensive value is a parameter to comprehensively measure the accuracy and recall rate, which can objectively reflect the trend of accuracy and recall rate, so the more complex the model is, the higher the comprehensive value is.

The accuracy rate of the DCLSTM-MLP model reached 94.82%, which is significantly higher than that of the other models (MLP: 88.76%, Text-CNN: 92.46%, Text-LSTM: 92.35%, CNN-MLP: 93.68%, and CLSTM: 93.0%). Also, the recall rate of the DCLSTM-MLP is 94.97%, and comprehensive value is 94.83% and is significantly better than that of the other models. Overall, the comprehensive value of the DCLSTM-MLP model is 94.83% which is higher than the other models in the percentage (MLP: 6.06%, text-CNN: 2.36%, text-LSTM: 2.47%, CNN-MLP: 1.14%, and CLSTM: 1.79%), which indicates that the combined model can improve the classification performance significantly.

5. Conclusion

The difference between the key features of news events and ordinary texts, as well as the obvious distinguishing features of all kinds of event news text keywords, is an important and challenging task. This paper solves the abovementioned problems and has the following three innovations. Firstly, a two-level classification model is designed. The first-level model identifies news events, and the second-level model implements news event classification. Secondly, different from the existing research, using word vector to express text feature information, this paper proposes a discrete vector to express text feature information, considering the contribution of each word in classification, and obtains the contribution of each word in classification by calculating the probability variance of each word. Finally, in the proposed model, the word vector and the dispersion vector are used to express the text features. The dispersion vector is used to represent the relationship between words and categories, while the word vector is used to represent the semantic information between words. Through the experimental comparison and analysis, in the two-level classification model proposed in this paper, the recognition rate of the first-level model is 99.5%, and the accuracy rate of the second-level model is 94.82%, which shows that the model has significant news event recognition and classification ability. The limitation of this paper is that the public stop word list is used in the text preprocessing, and the special stop word list corresponding to news is not constructed, resulting in some feature information being filtered out, and the special stop word list for news events can be established later. At the same time, the number of sample sets is small, and the number of various types of news is uneven, which leads to the limited effectiveness of the model. In the later stage, more sample sets need to be used for experiments. The limitation of this work is the future work of this paper.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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Research Article

English Grammar Error Detection Using Recurrent Neural Networks

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Automatic marking of English compositions is a rapidly developing field in recent years. It has gradually replaced teachers' manual reading and become an important tool to relieve the teaching burden. The existing literature shows that the error of verb consistency and the error of verb tense are the two types of grammatical errors with the highest error rate in English composition. Hence, the detection results of verb errors can reflect the practicability and effectiveness of an automatic reading system. This paper proposes an English verb's grammar error detection algorithm based on the cyclic neural network. Since LSTM can effectively retain the valid information in the context during training, this paper decided to use LSTM to model the labeled training corpus. At the same time, how to convert the text information in English compositions into numerical values for subsequent calculation is also an important step in automatic reading. Most mainstream tools use the word bag model, i.e., each word is encoded according to the order of each word in the dictionary. Although this encoding method is simple and easy to use, it not only causes the vector to lose the sequence information of the text but also is prone to dimensional disaster. Therefore, word embedding model is adopted in this paper to encode the text, and the text information is sequentially mapped to a low-dimensional vector space. In this way, the position information of the text is not lost, and the dimensional disaster is avoided. The proposed work collects some corpus samples and compares the proposed algorithm with Jouku and Bingguo. The verification results show the superiority of the proposed algorithm in verb error detection.

1. Introduction

For English learning, grammar and practice are extremely important. Writing is an effective way to test and improve the grammar. Hence, English learner needs to carry out a lot of writing training to improve their English proficiency [1, 2]. On the one hand, due to the increasing importance of English, there are more and more learners. At the same time, the number of English teachers is growing slowly, and teaching resources are becoming more and scarcer. Because the correction of composition is difficult and it takes much longer time, the feedback period from the teacher after students' practice is longer. Thus, the longer the feedback period, the worse the effect, affecting the learning of the individuals. In daily teaching, an English teacher usually needs to teach several classes of English at the same time. The teaching task is extremely heavy, and it is difficult to spend a lot of energy on reviewing composition.

China has a large population and an increasing number of English learners. However, China's basic education resources are relatively deficient, which is quite different from that of developed nations. Nowadays, the scale of English test in China is getting larger and larger, and a number of teachers are needed to correct the composition. English has very complicated grammar rules, which require a lot of effort on the teacher's part. Many students cannot get targeted guidance in the training, so there is an increasing demand for using the computer to correct English compositions. Some regular English writing self-correcting systems, such as Bingguo and Jouku, have been used in many colleges and universities, which greatly relieve the pressure of English teachers in teaching and correcting English compositions

[3–6]. Moreover, in China's English database, the error rate of noun use is 8.4%, while the error rate of verb use is nearly twice, which is the most error-prone part of speech error. The most common mistakes in the use of verbs are subject-verb agreement [7–9] and verb tenses and forms. Therefore, the effect of verb detection is a key sign of the maturity of an English composition automatic reading system. Through usage and statistics, this paper finds that Jouku and Bingguo have poor performance in verb consistency and tense error. Therefore, it is important to improve the detection rate of verb grammatical errors for English composition automatic reading [10].

In view of the poor performance of the mainstream reading system in verb error detection [11–13], this paper proposes a grammatical error detection method [14–17] based on deep learning [18, 19], especially for verb consistency and verb tense. According to the dependence of verb tenses on context information, this paper uses the LSTM model's ability to retain context information to solve the problem of incorrect verb tenses. At the same time, different from the word bag model used in the mainstream reading system, the word embedding model is used in this paper to transform the text information into numerical information, which not only solves the shortcoming of missing the text position information in the word bag model but also solves the dimensional disaster that the word bag model may bring. The main contributions of this paper are as follows:

(1) This article uses the recurrent neural network technology to solve the problem of English grammar error correction and provides a simple and convenient way for English learners to use, which has a certain role in promoting the improvement of English learners' grammar level.

(2) This paper maps the text information to a low-dimensional vector space so that the position information of the text is not lost, and the dimensional disaster is avoided. Moreover, the superiority of the algorithm in the error detection of English verbs is proved through experiments.

The rest of the paper is organized as follows. In Section 2, the background information relevant to the proposed work is presented. In Section 3, the proposed methodology adopted by our work is presented. In Section 4, the experimental results are provided. Finally, the paper is concluded, and future research directions are provided in Section 5.

2. Background

2.1. Related Research. One of the classic problems in the field of natural language processing [20–22] is machine translation [23]. The development of machine translation is a microcosm of the development of natural language processing. From the expert system at the beginning to the rule-based and grammar tree and then to the statistical probability method, a set of solutions have been formed. Grammatical error correction is similar to the process of machine translation, in which there are many lessons to be learned, and its development is also similar. At the beginning of the development of grammar correction, common grammar checkers were also rule-based, but due to the complexity and changeability of English grammar, it is basically impossible to rely on exhaustive grammar rules to detect errors. The late statistical machine translation technology has been introduced into grammar error correction, which is based on statistical experience and data-driven approach, and has received certain attention, which greatly promotes the development of grammar error correction.

For single grammatical errors of verbs, there is no special algorithm to solve them. The mainstream automatic marking systems all use a unified algorithm to solve all grammatical errors. At present, it has produced obvious results. For example, the United States has successfully made use of computer correcting in the process of correcting the TOEFL test. At present, grammar detection is mainly carried out by the rule detection model, but the complexity and diversity of English grammar result in the limitation of rule model detection, which cannot fully realize the function of error correction. However, the rule model is not very complicated and convenient to use, so various grammar detection systems generally choose this model.

Easy English grammar detection system [24], an IBM product, is based on the "English slot language model" (English Sbt Grammar), using the syntax tree to carry out error correction. The system successfully converts grammatical problems into pattern problems, enabling it to pair with the syntactic tree, but one problem that this system cannot solve is that not all sentences can be successfully decomposed and a complete syntactic tree can be constructed. Microsoft Word contains tools for checking spelling and grammar. High detection efficiency is one of its advantages. Precisely because of its superior performance in all aspects, it has become the benchmark for many grammar checking systems. The main function of Word is text editing, and grammar error checking is only an auxiliary function. Therefore, there is no special research on verb errors, resulting in a very low detection rate of verb errors. Link Grammar Parser is essentially a rule-based detection system, but it is different from the traditional rule-based detection system. The basic idea is to connect two sentences, which can replace the traditional method of tree structure analysis. After the experiment, the link grammar has high accuracy in judging sentences. In addition, according to the definition of different links, the link grammar itself also indirectly provides a tool for evaluating sentences. Since the rules for verb errors are complex and difficult to define, the detection effect of most grammar checkers on verb errors depends heavily on the definition of the rules.

2.2. Grammar Check. The design technology of the grammar detection model is generally based on natural language processing, i.e., marked part of speech, word segmentation, corpus, and other basic technologies.

2.2.1. Word Segmentation. For natural language processing, words are atomic units. Word segmentation refers to parsing a paragraph or a sentence into individual words, combining the words for analysis, in order to achieve the effect of studying sentencing problems. Therefore, word segmentation technology is the first step of the entire language processing program. Only by accurately and effectively decomposing sentences into individual words can the overall effective detection be carried out. Because English itself has obvious characteristics, there are spaces or other symbols between words for segmentation, so when studying English, the difficulty of segmenting English sentences is relatively low. However, the segmentation of English vocabulary is also difficult, mainly in how to correctly judge the ending position of the sentence.

At present, the common word segmentation techniques include the rule model-led word segmentation techniques and the statistical model-led analysis techniques. Rule model-driven analysis techniques store word classification as rules in the system, such as "can't," which can be divided into "can" and "not" by corresponding rules. Statistical model-based word segmentation techniques usually analyze the rationality of sentences under various word segmentation methods and finally produce the optimal word segmentation results.

2.2.2. Part-of-Speech Tagging. The part-of-speech marking system is based on the grammatical coherence, which marks the constituent words of a sentence with different parts of speech. Rule model dominance and statistical model dominance are two common implementations. Early part-of-speech taggers usually adopted a rule-based approach. PoS tagging is done manually by linguists according to language rules. The most representative one is the Taggit marking system, in which 86 kinds of marking sets can mark the part of speech, and there are more than 3300 contextual association rules. Brown corpus contains 1 million words, and the accuracy of word marking is up to 77%. This kind of form takes time and experience and cannot maintain absolute objectivity. It is difficult to guarantee the consistency of rules all the time, and problems such as contradictions and incompleteness among rules easily occur.

2.2.3. Corpus. Corpus can be regarded as a structural synthesis of a large number of texts, and the texts are all commonly used language vocabulary. The current corpus is usually stored in electronic devices and analyzed and sorted by computers. Corpus is very common in practical applications, which is generally applicable to hypothesis testing, static analysis, resource query, verification of linguistic rules, etc. In order to give full play to the function of the corpus in research, it is necessary to carry out preliminary processing work. For example, some small-scale corpora will be marked with PoS marking and other methods, and some will mark the lexical prototype. Smaller corpora usually contain 1 million to 3 million lexical data, which are usually annotated and parsed or deeply parsed in terms of semantics or morphology. A large amount of information can be obtained by studying these marked corpora, which is of great help to the technical development of computer language, computer translation, and speech recognition. Corpus can not only produce hidden Markov chains but also support English teaching according to vocabulary usage rate. There are several classifications of corpus. According to corpus balance and representativeness, corpus can be divided into two categories: balanced corpus and parallel corpus. According to the use, it can be divided into two categories: special and general corpus. According to time, it can be divided into two categories: diachronic and synchronic corpus. In addition, it can be divided into two categories according to the content: markup and raw corpus.

3. Methodology

3.1. Problem Definition. Common misclassifications of verbs in college English composition include (1) verb missing errors, (2) verb model errors, (3) verb tense errors, and (4) subject-predicate coincidence errors. The distribution of these four error types is shown in Table 1.

3.2. LSTM Verb Grammar Checking Model Based on the Transformer Attention Model. Information present before and after the text is crucial for checking grammatical errors and complementing the text, accordingly. When the LSTM model based on the attention model is used for syntax error checking, the full-text information is not fully considered, which leads to the missing of potential information. In dealing with this problem, Bi-LSTM model [25] is referred. In other words, the forward transfer information layer and the backward transfer information layer can, respectively, obtain the prior and subsequent text information of the sequence input into the system, and the latent layer of the forward and backward transfer layer with the same input node can input the final layer information after combining. The LSTM model based on the attention model [26], combined with the positive order and the negative order, is designed as the model structure, as shown in Figure 1.

It can be seen from Figure 1 that $x_1, x_2, \ldots, x_t$ is the sequence entered into the system, $h_1, h_2, \ldots, h_t$ represents the potential node of the layer whose transfer direction is forward, and $h_1', h_2', \ldots, h_t'$ denotes the potential node of the layer whose transfer direction is backward. $Y_1, Y_2, \ldots, Y_t$ denotes the final output sequence.

The following assumptions are taken into account:

(1) Input both positive and reverse sequences into the model. $x_t, x_{t-1}, \ldots, x_1$ and $X\prime$ are inverted sequences, and the rest are positive sequences. The word vectors are formed from the two sequences' input by word embedding technology, and then the results are input into the LSTM model based on the attention model.

(2) Input both positive and reverse sequences into the feature extraction part of LSTM based on the transformer attention model, so as to obtain semantic coding of two related information containing the correlation degree of input to output sequences. Combining the two can be used as the final semantic

Table 1: Parameters corresponding to the experimental environment.

Type of error	Error percentage
Verb missing errors	5
Verb modal errors	20
Verb tense errors	36
Subject-predicate coincidence errors	39

encoding so that all the information of the text is taken into account.

(3) The semantic coding obtained after the combination of the forward and reverse semantic coding is the vector that can be used to build the categorized system. Logical regression is used to design the classifier.

In model training, word vector generation module and feature extraction module [27, 28] adopt the single-layer training method. Each layer first generates the word vector and then trains the attention-based LSTM feature extraction model to generate its respective semantic coding. In the training and testing part of the classifier, the two-layer structure is trained together, and the input of the classifier is the final semantic code generated after the combination of positive-order semantics and inverse semantics.

3.3. Transformer. The transformer model contains an encoder and a decoder [29]. Figure 2 shows the structure of the model. Given the source-end error sentence, i.e., $x = (x_1, x_2, \ldots, x_m)$, $x_i \in X$, X is the source-end vocabulary. Here, the transformer encoder encodes x as a set of implicit states in a continuous space, representing $e = (e_1, e_2, \ldots, e_m)$. Based on this representation, the transformer decoder generates target-side corrected sentences $y = (y_1, y_2, \ldots, y_m)$, $y_i \in Y$, time by time, and Y is the target-side vocabulary.

The encoder and decoder in the transformer, respectively, contain 6 identical layers. The layer located in the encoder consists of a self-attention sublayer and a forward neural network complex sublayer. The input first passes through the self-attention sublayer, and then the same forward neural network is applied to the output at different locations in the self-attention sublayer. The layer located in the decoder also contains a self-attention sublayer and a forward neural network complex sublayer. In addition, there is an encoder-decoder attention sublayer in between the two, which is similar to the attention layer in the typical encoder-decoder model of the cyclic neural network. At the output of all sublayers of the encoder and decoder, the residual connection is applied, and the layer normalization is done.

3.4. Attention Mechanism in the Transformer. Given the query vector q, the key vector set K, and the value vector set V, the calculation equation of the zoomed point product attention is as follows:

$$\text{scaAttention}(q, K, V) = \text{softmax}\left(\frac{qK^T}{\sqrt{d_k}}\right). \tag{1}$$

Here, d_k represents the dimension of the key vector, and the scaling factor $(1/\sqrt{d_k})$ is introduced to prevent the probability distribution calculated by softmax from being too extreme, resulting in too small gradient when the parameter is updated.

To allow the model to obtain information from different representation subspaces at the same time when encoding at different positions in the sequence, the multiheaded attention will perform multiple scaled point-multiplying attention calculations.

$$\begin{aligned} \text{MultiHead}(q, K, V) &= \text{Concat}(\text{head}_1, \text{head}_2, \ldots, \text{head}_h)W^O, \\ \text{head}_i &= \text{scaAttention}\left(qW_i^Q, KW_i^K, VW_i^V\right). \end{aligned} \tag{2}$$

The dimensions of each projection matrix are, respectively, W_i^Q, W_i^K, W_i^V, and W^O. d_{model} is the dimension of the unified input and output of all layers in the transformer model, d_v is the dimension of the value vector, and h is the number of times of scaAttention performed at each position in the sequence.

Since the transformer model does not contain any loop structure, in order to take advantage of the location information of the symbols in the sequence, the location encoding is incorporated into the input embedding. The dimensions of the location encoding are the same as the dimensions of the transformer model's implied DMode. The specific calculation equation is as follows:

$$\begin{aligned} PE_{(\text{pos},2i)} &= \sin\left(\frac{\text{pos}}{10000\,(2i/d_{\text{model}})}\right), \\ PE_{(\text{pos},2i+1)} &= \cos\left(\frac{\text{pos}}{10000\,(2i/d_{\text{model}})}\right). \end{aligned} \tag{3}$$

Here, pos is the position label of a symbol in the sequence, and i indicates a component of the position encoding vector.

3.5. Model Training. When training the transformer, maximum likelihood estimation is used. The goal is to maximize the likelihood of the model on the training data S:

$$\theta = \arg\max_{\theta} \sum_{(x,y)\in S} \log\, p(y|x;\theta). \tag{4}$$

4. Experiments and Results

4.1. Experimental Setup. I train the model on two GeForce RTX 2080 Ti, the batch size is set to 256, the maximum sentence length is set to 50, the part exceeding this length is directly truncated, and the update stops after about 30,000 steps. The source end and the target end use different vocabularies, and the first 30,000 BPE subword units that appear most frequently are, respectively, taken. When

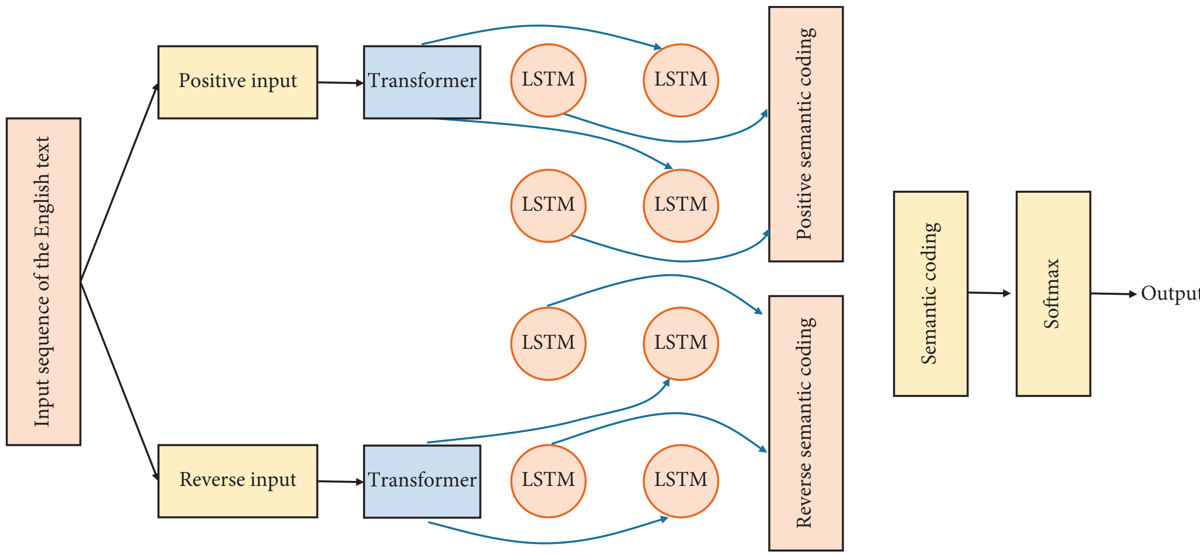

FIGURE 1: Schematic diagram of the English grammar detection model.

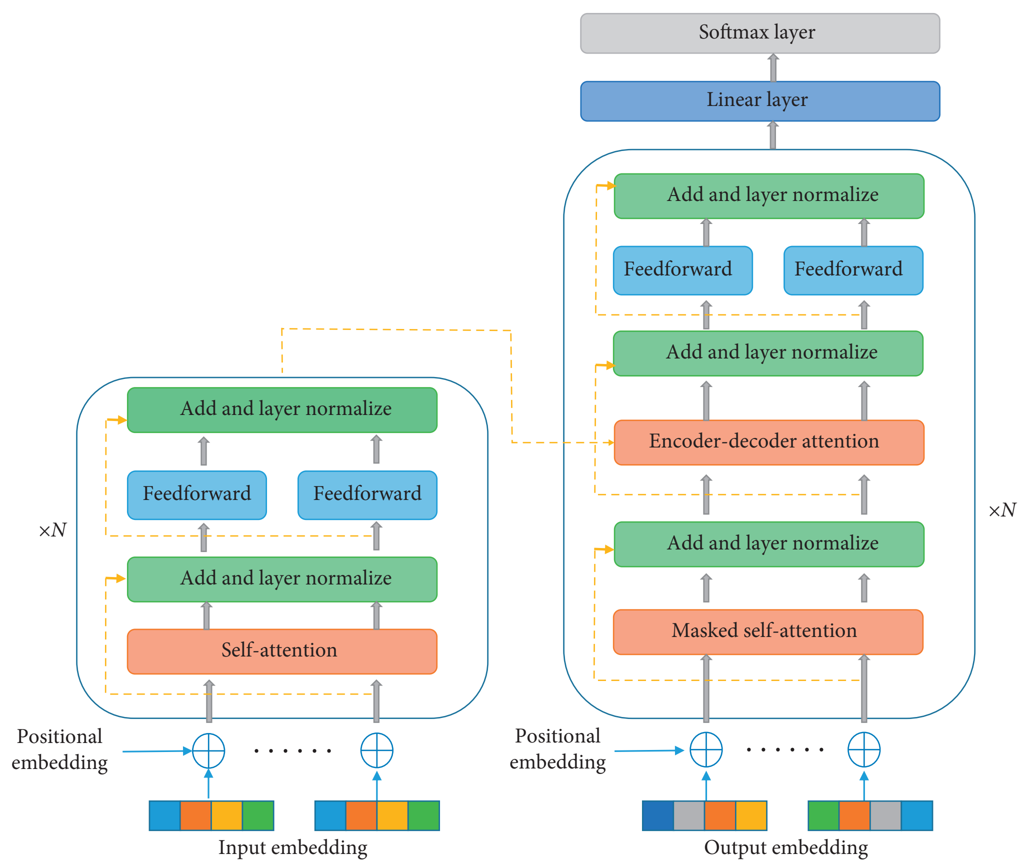

FIGURE 2: Schematic diagram of the transformer model structure.

decoding, the beam search with length penalty is used, the beam size is set to 8, *a* parameter in the length penalty is set to 0.6, and the maximum length of the generated corrected sentence is set to 300.

4.2. Datasets. The dataset used for the experiment in this paper is the Chinese Learner English Corpus (CLEC), which contains more than one million composition materials written by middle and college students in China.

Table 2: F-value of the grammar check module on the CLEC test set.

Behavior	P	R	F
Verb error detection	0.4515	0.3256	0.3599
Subject-verb consistency error detection	0.4266	0.2569	0.3358
Overall error detection	0.8396	0.2965	0.7725

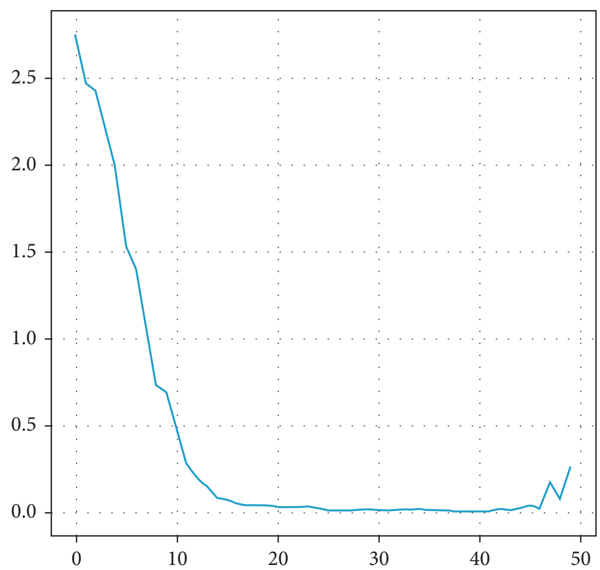

Figure 3: Training loss of our model.

The editor of the corpus has marked the grammar and errors of all the materials in the corpus. Due to the complicated work and huge project, it is called the first language material library officially open to the world to mark language errors for English learners. In this paper, 100 CLEC English compositions were randomly selected for the experiment. There were a total of 1128 sentences in the 100 compositions, including 1083 wrongly marked sentences.

4.3. Evaluation Methods. We generally use F-measure, which is F-score, to evaluate and measure the results and effectiveness of error checking. Therefore, this article uses F_1-measure, and its calculation equation is as follows:

$$F_1 = \frac{P * R}{P + R}. \quad (5)$$

Here, P stands for precision and R for recall, respectively.

4.4. Experimental Results. As can be seen from Table 2, the algorithm in this paper has played its role in improving the accuracy of checking whether the grammar is positive or negative, and at the same time, the F-value has been improved to a certain extent. In addition, this paper also conducted a comparison of the same type system, namely, Jouku.com, and the results show that Jouku.com has a recall rate of 0.487 for grammatical errors, while its accuracy rate is 0.897. Therefore, we can realize that our system has a higher accuracy than Jouku.com, but there is a certain gap in recall rate. By analyzing the reasons, the insufficient number of rules leads to a lower recall rate. There are less than 1100 rules in the system studied in this paper, while there are more than 5000 rules in Jouku.com. Therefore, in order to improve the recall rate, the system must increase the quantity and quality of its own rules. In addition, a comparison with the GCSCL using the CLEC test set showed that our system had an accuracy rate of 77%, and the recall rate was improved. Figure 3 also shows the training loss curve, which can be seen to be very smooth. In addition, Figures 4–6 also show the histograms on precision, recall, and F-score, which clearly show the effectiveness of our model.

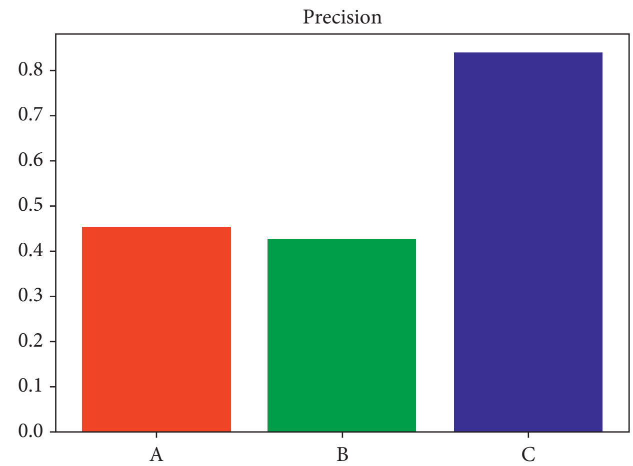

Figure 4: Precision histogram of our method: A represents verb error detection, B represents subject-verb consistency error detection, and C represents overall error detection.

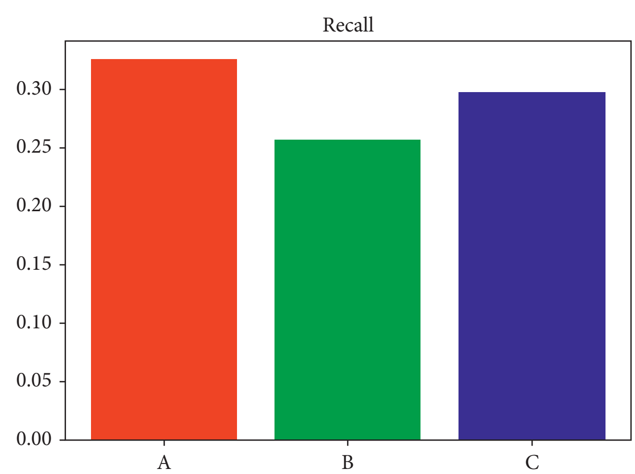

Figure 5: Recall histogram of our method: A represents verb error detection, B represents subject-verb consistency error detection, and C represents overall error detection.

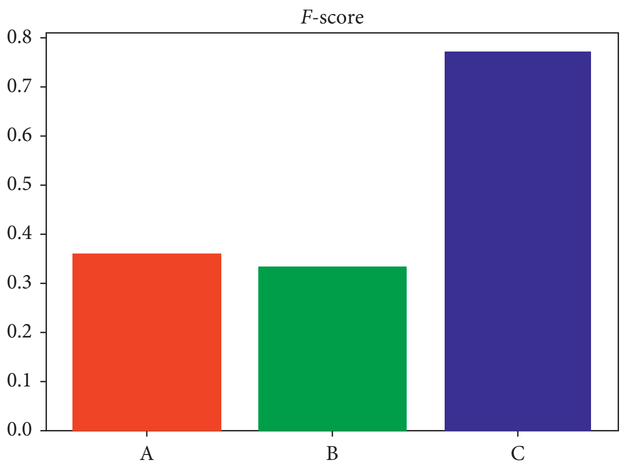

Figure 6: *F*-score histogram of our method: A represents verb error detection, B represents subject-verb consistency error detection, and C represents overall error detection.

5. Conclusion

This paper proposes an error detection algorithm for English verbs based on a recurrent neural network. Since LSTM can effectively retain adequate information during training, this paper uses LSTM as a training model for the labeled training corpus. At the same time, how to convert the text information in the English composition into numerical values for subsequent calculations is also an essential step in automatic review. Most mainstream tools use the bag-of-words model, where each word is encoded according to its order in the dictionary. Although this encoding method is simple and easy to use, it causes the vector to lose the sequence information of the text and is prone to dimensional disasters. Therefore, this paper uses the word embedding model to encode the text and maps the text information to a low-dimensional vector space. The text's position information is not lost, and the dimensional disaster is also avoided. Next, this paper collects specific corpus samples and compares and verifies the algorithm in this paper with Jouku and Bingguo, respectively. The verification results show the superiority of the algorithm in verb error detection.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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Research Article

Feature Design Assessment of the Ship Fire Alarm System

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Damages and misfortunes caused by fire on ships have recently accelerated the creation of new approaches, development, and building the security and unchanging quality of the fire detection framework. Simultaneously, with the growing interest in better early fire detection and prevention, numerous frameworks are being created for the detection of progress, with control calculations having the task of carefully preparing and identifying true/false signals from fire or flames or the true alarm from false alarms. By utilizing the assistance provided by innovation, transport owners are more likely to service groups and fleets of ships and reduce potential fire accident costs. This article provides an overview of recent methodologies and technology for early detection of ship fires, as well as an enhanced approach for evaluating the Human-Machine-Interface (HMI) function of an alarming ship using a machine operating simulator called DMS-2017B. The DMS-2017B machinery operation simulator can unify the noise environment to avoid the influence of environmental differences on cabin experimental results. Compared to conventional Binomial Testing, a ship simulator coupled with the theory of affordance that provides a more realistic and operable way to assess the feature design of ship fire alarm and the threshold of some influence factors can also be used. According to the quantitative analysis of experimental results based on the ordered logit model, the function of the ship fire alarm would be improved significantly by adding recorded broadcasting and replacing static symbols with flashing symbols. Increasing sound pressure is also an effective way of doing this, but an auditory threshold is present. Above 75 dB, this effect will fade down, along with noise pollution. However, the effect difference between continuous alarm and square wave pulse alarm is negligible. The conclusion can provide some guidance for the design of a ship fire alarm. An appropriate design is expected to facilitate the efficiency of handling accidents and guiding evacuation.

1. Introduction

The primary goal of a fire alarm system is to offer an advance indication of a fire so that people can be removed and prompt action can be taken to minimize or eliminate the fire's effect. For this purpose, detectors or a manual call point can be used to set off an alarm. There are dozens of ship alarms and call signals. These alarms can be divided into four classes by priority level: emergency alarm, alarm, warning, and caution [1, 2]. All alarms are required to indicate by audio and visual means to keep the visual alarm unaffected when the audible alarm is interrupted by a notice and make sure that all passengers and crew members can receive alarm information in an unobstructed manner [3–5]. Accidents and casualties cannot be avoided from happening, even if marine vehicles are installed with the warning system that is exactly specified by IMO [6, 7]. Over 500 major marine accidents happened after 1980; as of 2010, death tolls hit 1,824 [8–10]. On 16 April 2014, MV SEWOL heeled at turning, resulting in 296 deaths and 8 persons reported missing [11]. It was alarmed when this accident occurred, but high school students as a part of passengers remained still and failed to evacuate right away, resulting in 250 deaths [12]. As indicated by the United States fire administration [13], the assessment of yearly private structure fire deaths in the United States is somewhere in the range of 2385 and 3050 from 2003 to 2012. The investigation of [14] shows that one out of four (1/4) lasting inhabitants (24.2%) were sleeping at the hour of start, while in flames that brought about fatalities, four out of five lethally harmed (80.5%) were snoozing. The US fire administration reports that over 88% of the homes in the United States have at any rate 1 fire alert introduced. However, 60% of the private fire deaths happen in homes without an operational caution analysis of information from the United States fire organization's national fire incident reporting system (NFIRS) and the NFPA's fire office study showed that from 2003 to 2006, no fire alerts were available in 31% of revealed home flames and 40% of home fire deaths [15]. It matters that alarm can be understood and trusted. The feature design of ship alarm has been preferably discussed in present works.

Extensive works related to the design of fire alarm systems have revealed that the design of alarm features often decides whether information can be noticed and understood. For instance, the volume test of fire alarm found that 20% of persons are unable to properly respond to 60 dB fire alarm due to background noise, signal meaningfulness, signal frequency, hearing loss, time of night, and stage of sleep. Instead, 90 dB fire alarm leads to better results [16–18]. Wireless fire alarm systems should fulfill current criteria, be simple to install, quick, and inexpensive, and avoid damaging the surface of the structure by causing the slightest alterations in the features of easy adaptation [19]. Another work suggested that a fire alarm should be added with the broadcast so that the alarm information can be further understood and recognized [20]. Another associated work revealed that dynamic signs would be more visible than static signs, which means an increase of visibility level from 38% to 77% [21].

A simple comparative experiment is often carried out to compare the difference of a single feature of alarm. If more features need to be considered, statistical algorithms are generally used to avoid mistakes and estimation errors [22]. Binomial testing is a traditional method to assess the effect of the feature design of emergency evacuation appliances. This paper is intended to observe the feature design effect of ship fire alarms and identify which feature may be modified to make persons better aware of alarms. Ship simulator was used to acquire experimental data and filter errors. Results were analyzed using the ordered logit model and then compared with the findings of real experiments and binomial testing. The reliability, strengths, and weaknesses of the proposed procedure were validated. The main contributions of the proposed study are listed in the following:

(i) Numerous human deaths occur in ships due to fire. The proposed scheme helps to save important human lives by designing an intelligent ship alarm system.

(ii) This paper offers an approach to building a ship fire alarm by using the DMS-2017B machinery operation simulator.

(iii) The proposed ship simulator is coupled with the theory of affordance that provides a more realistic and operable way to assess the feature design of the ship fire alarm system.

(iv) In addition, both continuous alarms and pulse alarms are incorporated as a part of the auditory feature design of ship fire alarms.

(v) Finally, various simulation experiments such as the Cabin experiment and Binomial testing are conducted to verify the advantage of the method in the ship fire alarm system. The results of three experiments indicated that the sound pressure increased from 60 dB to 75 dB and replacing static signs with dynamic signs can significantly enhance the function of the fire alarm under the noise environment in a ship's cabin.

The rest of the paper is organized as follows. In Section 2, we discuss the materials and methods for the proposed approach. In Section 3, we explain our experimental works. A short discussion of the proposed scheme is presented in Section 4 and the conclusion is provided in Section 5.

2. Materials and Methods

2.1. Fire Alarm System. The Fire Alarm System is intended to notify us of an emergency so that we can take appropriate measures to protect ourselves, our employees, and the general public. Fire alarms are discovered in ships, offices, factories, and public buildings; they are a part of our daily routine but are easily ignored until an emergency occurs, at which point they may save our lives. Whatever method of identification is used, if the sensor is activated, sounders will sound to alert people in the area that there may be a fire and to advise them to evacuate. The fire alarm system may include a remote signal system that alerts the fire department via a control center. The Fire Alarm Control Panel is the "brain" of the fire detector system. It serves as the central hub for all detector signals and displays a status indicator to users. The detection systems are at the heart of a fire alarm system, ranging from complex, intelligent fire alarms to simple manually operated break glass units. There are many different types, but we can categorize them into five types [15] as in Figure 1.

2.1.1. Heat Detector. Heat detectors can operate on a specified temperature basis, triggering an alarm if the temperature exceeds a preset value or on the rate of variations in climate. Heat detectors work similarly to electrical fuses in that they encompass a eutectic alloy that is heat-sensitive; if a certain threshold is achieved, the alloy transforms from a solid to a liquid, triggering the alarm.

2.1.2. Smoke Detectors. This kind of detectors can be classified into three types [17]:

(i) *Ionization*. Ionization, a smoke alarm typically has two tubes. The first one is used to compensate for changes in temperature, humidity, or pressure. The second chamber consists of a radiation material, typically an alpha particle, which ionized particles the air passing through the chamber, which includes 2 electrodes and a current flowing among both them. The flow of current tends to decrease when smoke enters the chamber. This decrease in current flow is used to set off an alarm.

(ii) *Light Scattering*. The Tyndall effect is used in the light scattering smoke alarm; a photocell and a light

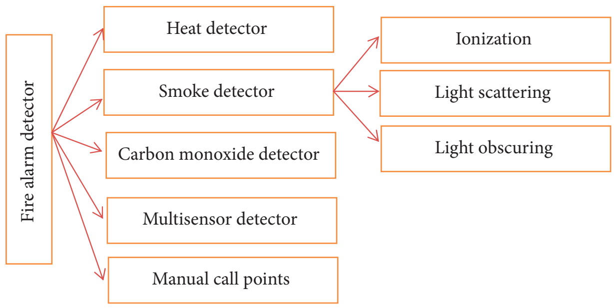

FIGURE 1: Fire alarm detectors.

source are segregated by a darker chamber so that the light source does not fall on the photocell. The passing of smoke into the chamber scatters the light from the origin, which falls on the photocell. An alert system is being triggered by the photocell output.

(iii) *Light Obscuring*. Smoke interferes with such a light beam between a light source and a photocell in the Light obscuring fire alarm. The photocell detects the amount of light that strikes it. A variance in photocell output is being used to trigger an alarm. With the light source and photocell placed some distance away, this sort of fire detection system can be used to protect huge regions [23].

2.1.3. Carbon Monoxide Detectors. Carbon monoxide detection systems, also recognized as CO smoke detectors, are digital sensors that detect the presence of carbon monoxide in the air and alert the user to the presence of a fire. Carbon monoxide is a highly toxic gas that is produced during the combustion process. These sensors are not the same as carbon monoxide detectors, which are used in homes to safeguard citizens from carbon monoxide generated by incomplete combustion in equipment such as gas fires or boilers. Carbon monoxide flame detectors use the same type of sensor as household sensors, but they are more sensitive and respond faster.

2.1.4. Multisensor Detectors. Multisensor detectors merge optical and temperature sensor inputs and procedure those using a sophisticated algorithm constructed into the detector circuit board. When the sensor is polled by the control panel, it returns a value determined by the combined responses of the optical and heat sensors. They are intended to be resistant to a wide range of burning.

2.1.5. Manual Call Points. A Manual Call Point, also known as a Break Glass Call Point, is a device that allows staff to sound the alarm by breaking the frangible component on the fascia, triggering the alarm.

2.2. DMS-2017B Machinery Operation Simulator. A simulator is an operable device developed by computer software for simulation and training, which is often used to replace real disasters and accident experiments to avoid personal injury [24]. The experimental environment is volatile due to the flow of persons and changes in ship sailing conditions, resulting in great deviation of environmental impact factors during each experiment. DMS-2017B machinery operation simulator was tailored for this experiment in order to avoid these external factors from causing impact and personal injury DMS-2017B machinery operation simulator is shown in Figure 2; this simulator can simulate the operation of cabin facilities and different fire scenes using unity3D engine; an operator can simulate the behaviors of crew members or passengers in cabin from the first-person perspective [25]. Unity is a cross-platform game engine for creating video games and simulations for PCs, consoles, smart applications, and websites. It was first introduced just for OS X at Apple's Worldwide Developers Conference in 2005 and has been expanded to practically every accessible platform. It is developed by Unity Technologies. A three-dimensional (3D) engine, often known as a game engine, is a system that allows virtual computer simulations to be created. A 3D engine contains various areas of operation that work together to create a digital world that is both immersive and realistic. A gaming engine's rendering element determines a scene's visual look, while the physics component decides how different objects should interact. Some engines additionally offer realism-enhancing tools like scripting and artificial intelligence. Moreover, the DMS-2017B machinery operation simulator program, which incorporates the theory of affordances, can assess the HMI function of shipboard alerts. A Human-Machine Interface (HMI) is a user interface or dashboard that links a person to a machine, system, or device and can be used to visually display data, track production time, trends, and tags and Monitor machine i/o in the industries of energy, oil, and gas, manufacturing, power, and transportation, etc. According to the Theory of Affordances, people see the environment not only in terms of object shapes and particular relationships but also in terms of object action possibilities (affordances)—seeing a thing implies seeing the action connected with it [26]. Under the framework of the Theory of Affordances, assume that the degree of affordance of an object is associated with the information it provides. The affordance of this object can be divided into the following four levels:

(1) Sensed (Sensory Affordance)
(2) Understood (Cognitive Affordance)
(3) Physically used (Physical Affordance)
(4) If it fulfills its intended goal (Functional Affordance) [27]

Illustrating the alarm system as an example, the alarm cannot be physically used by crew members or passengers, but it can hint persons to give proper responses. After steps are modified, the affordance of alarm features can be divided into the following five levels:

(1) The alarm is not noticed
(2) The alarm is noticed, but the hazard information to be transmitted is not understood

Figure 2: DMS-2017B machinery operation simulator.

(3) The information transmitted by the alarm is understood, but the action hinted by the alarm is not understood

(4) The action hinted by the alarm is understood, but the intended goal is not fulfilled

(5) Its intended goal is fulfilled

DMS-2017B machinery operation simulator is shown in Figure 2.

The simulator judged the feature design effect of the alarm by collecting the data about the behaviors and choices of subjects after the alarm sounded. The subject will receive a further questionnaire survey if the alarm has not yet fulfilled its intended goal within a given time after the alarm sounds. Those persons who failed to complete the questionnaire survey were deemed as invalid data and excluded from the statistical record.

According to theory of affordances, the degree of affordance of an object will level up. In this sense, the alarm should be noticed before understanding the hazard information transmitted by the alarm and knowing which action to be taken. Any data violating this level-up logic will be deemed as error data. Table 1 lists the judgment of data types.

The ordered logit model is a linear regression for dependent variables with an ordered value. The system is based on the response variable's accumulated probabilities: each cumulative probability's linear regression model is considered to be a linear function of the variables, with Regression Coefficients constant across Response Categories [28]. The collected data were analyzed using the ordered logit model. Assume that N persons are affected by a thing, $i = 1, 2, 3 \ldots, N$, and one of them, i, the level of affordance Y_i he gained is subject to the HMI impact, then Y_i can be only decided by the latent variable of the thing, D_i. According to the ordered logit model, the latent variable D_i can be written as follows [29]:

$$Di = \sum_{K=0}^{K} \left(B_k X_{ik} + \varepsilon_i\right) = Z_i + \varepsilon_i. \quad (1)$$

The latent variable D_i is equal to a linear function decided by K factors of the thing, $k = 1, 2, 3 \ldots, K$, X_{ik} refers to the value of the k_{th} factor of the thing, β_k refers to the correlation coefficient of the k_{th} factor of the thing. The error term ε_i in the above equation deals with inaccurate measurement or any factor not included. When $\beta_k > 0$, the k_{th} factor of the thing is considered to be greater and the degree of affordance of this thing increases. When $\beta_k < 0$, the k_{th} factor of the thing is considered to be smaller and the degree of affordance of this thing also increases. Take the ship alarm system as an example. Its alarm volume, whether auxiliary language broadcast is used, and the display mode of signs can be considered as relevant factors of the alarm.

Y_i is based on the latent variable D_i and the threshold value $(\delta_1, \delta_2, \delta_3 \ldots, \delta_n)$, as shown as follows:

$$\begin{aligned} &Y_i + 0, \quad \text{if } D_i < \delta_1, \\ &Y_i = 1, \quad \text{if } \delta_1 \le D_i < \delta_2, \\ &Y_i = n - 1, \quad \text{if } \delta_{n-1} \le D_i < \delta_n, \\ &Y_i = n, \quad \text{if } \delta_n \le D_i. \end{aligned} \quad (2)$$

Take the alarm system as an example, the affordance of the alarm is divided into five levels; the level of affordance other than external factors depends on whether the latent variable Di has spanned over a threshold value then the probability of $Y_i = 0, 1, 2, 3, 4$ can be written as follows [30]:

$$\begin{aligned} &P(Y_i = 0) = P(Z_i + \varepsilon_i < \delta_1) = F(\delta_1 - Z_i), \\ &P(Y_i = 1) = P(\delta_1 \le Z_i + \varepsilon_i < \delta_2) = F(\delta_2 - Z_i) - (\delta_1 - Z_i), \\ &P(Y_i = 2) = P(\delta_2 \le Z_i + \varepsilon_i < \delta_3) = F(\delta_3 - Z_i) - (\delta_2 - Z_i), \\ &P(Y_i = 3) = P(\delta_3 \le Z_i + \varepsilon_i < \delta_4) = F(\delta_4 - Z_i) - (\delta_3 - Z_i), \\ &P(Y_i = 4) = P(\delta_4 \le Z_i + \varepsilon_i) = P(\delta_4 - Z_i \le \varepsilon_i). \end{aligned} \quad (3)$$

$F(x) = P(\varepsilon_i < x)$ is the cumulative probability distribution function of the error term. If the ordered logit model is used, assume that $F()$ conforms to the logical distribution. The unknown parameters included in equations (1) and (3) are assessed by defining a likelihood function, the perceived degree of k_{th} factor on latent variable D_i is judged from β_k and P.

3. Experiment

This segment of the paper denotes the experiments performed and the simulation results of the DMS-2017B machinery operation simulator carried out through those experiments. Multiple simulation experiments were conducted on the DMS-2017B machinery operation simulator. Among the experiments and simulation results, the top two, such as cabin experiment and binomial testing experiment, are discussed here. By comparing the experimental results, we can better compare the differences between different experimental methods. All the experiments have been performed on a Laptop computer (Intel Core-i7, 7th generation, having a processor of 2.7 GHz, 32 GD RAM, and Windows 10 operating system).

3.1. Participants. The function of a ship fire alarm is to summon the crew to the fire station. In this sense, a ship fire alarm should be intended for the ship's crew. So the

Table 1: Affordance level judgment table.

If the intended goal is fulfilled after setting off	If no choice is made for there is any problem	If the alarm is noticed	If the information transmitted by the alarm is understood	If the action hinted by the alarm is understood	Level of affordance
Y	Null	Null	Null	Null	4
N	Y	Random	Random	Random	Invalid data
N	N	N	N	N	0
N	N	N	Y	Random	Error data
N	N	N	Random	Y	Error data
N	N	Y	N	N	1
N	N	Y	N	Y	Error data
N	N	Y	Y	N	2
N	N	Y	Y	Y	3

experimental participants were mainly students majoring in navigation and marine engineering. Participants are the students as holders of certificates of professional training for seafarers, passed the CCS English test for general seafarers, and can proficiently operate the DMS-2017B machinery operation simulator. Considering the eligibility for marine navigation, all participants are of the male gender, without color blindness and hearing impairment. 618 participants were chosen for this experiment, age group from 20 to 29, with an average age of 22 years old. Career experience and nationality were not observed as a part of this experiment and will be discussed in subsequent works.

To avoid the influence of previous experimental experience, the cabin experiment was classified into 6 groups, 25 different participants in a group, and the simulator-based experiment was classified into 6 groups, 48 different participants in a group. There are five groups of experiments in binomial testing. 36 different participants were assigned to each group.

3.2. Subjects. We have considered the feature design of the ship fire alarm here. Because a ship fire alarm has an auditory and visual function, the auditory and visual design of the fire alarm must accord with the IMO regulations applicable to shipboard alerts. According to the international maritime organization (IMO), ship fire alarms use a continuous alarm or a pulse alarm with a frequency ranging from 0.5 Hz to 2.0 Hz. Therefore, the waveforms used in the experiment are two kinds of commonly used continuous alarm or 1 Hz square wave alarm with high and low staggered signal frequencies. Previous works on alarm sound revealed that the alarm sound complemented with broadcast could improve the alarm effect. As a result, "Fire alarm, please go to the fire station," recorded broadcasting in Chinese and English languages, was added to the alarm sound as a new design type. Conventions and regulations only set out the minimum limits on the alarm sound pressure. For instance, LSA Code specifies that the upper limit of alarm sound pressure should not exceed 120 dB, and the ship alarm is generally designed above 60 dB with a minimum interval of 15 dB. Previous experiments on fire alarm sound pressure have affirmed that 90 dB can effectively wake up those who fall asleep. Therefore, we carried out works in the case of 60 dB, 75 dB, and 90 dB. For the fire alarm symbol, the IMO only specified the symbol with red color instead of specifying that the symbols should be static or dynamic. The static symbol is considered as the regular design. We added dynamic symbols at a flashing frequency of 1 Hz as a new design type. Feature combination design number reference of ship fire alarm is presented in Table 2.

Given the combination of different features (sound pressure, waveform, symbol type, broadcast type), there are 24 different designs as given in Table 2. 6 designs as mentioned below were examined to traverse the affordance of fire alarm feature design: DN1 is a static symbol, 60 dB, continuous alarm, no broadcasting; DN9 is a static symbol, 75 dB, continuous alarm, no broadcasting; DN10 is a static symbol, 75 d, continuous alarm, broadcast with Chinese and English recording; DN11 is a dynamic symbol, 75 dB, continuous alarm, no broadcasting; DN13 is static symbol, 75 dB, 1.0 Hz pulse alarm, no broadcasting; DN17 is a static symbol, 90 dB, continuous alarm, no broadcasting.

3.3. Simulator Experiment with DMS-2017B Machinery Operation Simulator. Figure 3, shows the scene constructed by the DMS-2017B machinery operation simulator according to the real objects in the cabin experiment. Figure 3(a) simulates the fire scene in the auxiliary engine room. Figure 3(b) shows the appearance image of DN1, DN9, DN10, DN13, and DN17. Figure 3(c) shows the appearance image of DN 11. At the beginning of the experiment, we told the participants to have operation training in the central control room. The participants appeared in the central control room as an intern and began the training from the first perspective. External speaker of the DMS-2017B machinery operation simulator will continue to make noise recorded in the cabin experiment to simulate the real cabin environment.

The top view of the cabin structure is shown in Figure 4. Similar to the installation position of the fire alarm in the cabin experiment, the fire alarm is installed near the door of the central control room in the simulator experiment. The walking time from the entrance of the central control room to the fire station is 56 seconds by using the path finding function of the simulator? The experiment was called to end in five minutes after the alarm was triggered, and the experimental data were collected for the statistical record. Any participant returning to the fire station by simulator control

Table 2: Feature combination design number reference of the ship fire alarm.

Fire alarm design number	Sound pressure (dB)	Waveform	Symbol type	Broadcast type
DN1	60	Continuous alarm	Static symbol	No broadcasting
DN2				Broadcast with Chinese and English recording
DN3			Flashing symbol	No broadcasting
DN4				Broadcast with Chinese and English recording
DN5		1.0 Hz pulse alarm	Static symbol	No broadcasting
DN6				Broadcast with Chinese and English recording
DN7			Flashing symbol	No broadcasting
DN8				Broadcast with Chinese and English recording
DN9	75	Continuous alarm	Static symbol	No broadcasting
DN10				Broadcast with Chinese and English recording
DN11			Flashing symbol	No broadcasting
DN12				Broadcast with Chinese and English recording
DN13		1.0 Hz pulse alarm	Static symbol	No broadcasting
DN14				Broadcast with Chinese and English recording
DN15			Flashing symbol	No broadcasting
DN16				Broadcast with Chinese and English recording
DN17	90	Continuous alarm	Static symbol	No broadcasting
DN18				Broadcast with Chinese and English recording
DN19			Flashing symbol	No broadcasting
DN20				Broadcast with Chinese and English recording
DN21		1.0 Hz pulse alarm	Static symbol	No broadcasting
DN22				Broadcast with Chinese and English recording
DN23			Flashing symbol	No broadcasting
DN24				Broadcast with Chinese and English recording

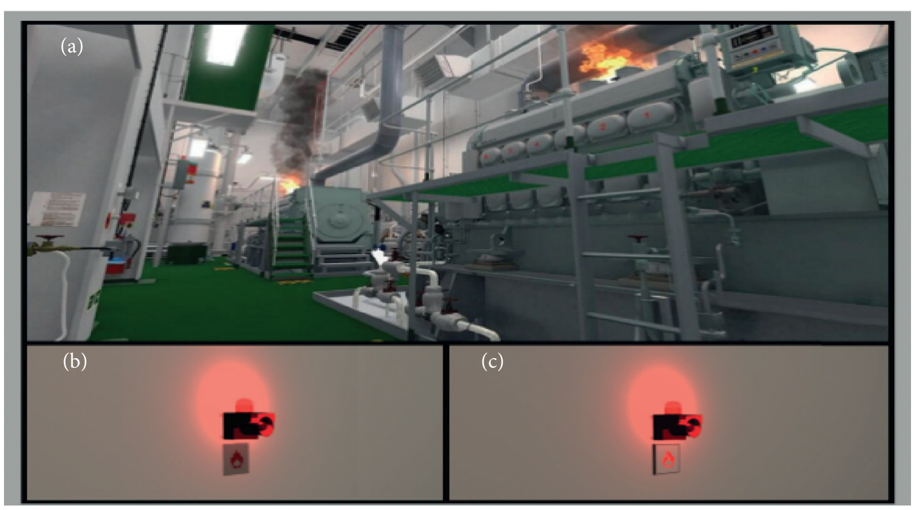

Figure 3: The scene constructed by DMS-2017B machinery operation simulator. (a) Fire scene in the auxiliary engine room. (b) Appearance feature of DN1, DN9, DN10, DN13, and DN17. (c) Appearance feature of DN11.

would be asked the question “did you arrive at the fire station because of the alarm,” anyone with an affirmative response was considered to fulfill the intended goal, and anyone with a denied response was considered as invalid data. Any participant who failed to return to the fire station would be asked the question “if you want to return to the fire station, but failed to do so for operation,” anyone with an affirmative response was considered to invalid data, and anyone with a denied response was further asked to answer three questions as presented in the following:

Question 1: did you notice the alarm?

Question 2: did the alarm let you obtain the information about a fire that has occurred?

Question 3: did the alarm let you obtain the reminder of gathering at the fire station?

The host collected all the experimental results of the simulators and judged the validity and affordance level of data against Table 1. For quantitative analysis, the experimental data were analyzed using the ordered logit model. The latent utility function which applies to the ship fire alarm system intended for this experiment can be written as follows:

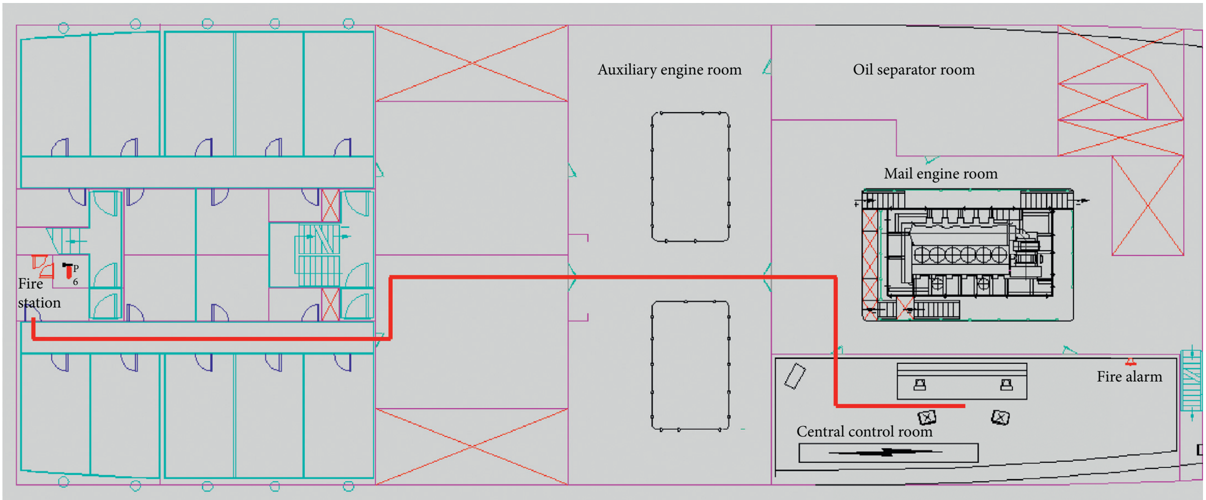

Figure 4: Top view of cabin structure in an experimental environment.

$$D = sS + wW + fF + bB + \varepsilon. \quad (4)$$

The latent variable D is associated with the value of sound pressure (S), waveform (W), symbol type (F), and broadcast type (B), where W, F, and B are the factors only with two values (0, 1), $W = 1$ if the waveform is pulse sound wave, $F = 1$ if the symbol type is flashing symbol. Of broadcast type, $B = 1$ if the original alarm is added with the recording broadcast. As S has three values (60 dB, 75 dB, 90 dB), it is generally treated as a covariate. To consider the auditory thresholds of sound pressure on alarm function, the first group consisting of 60 dB and 75 dB sound pressure data is analyzed by ordered logit model, and then the second group consisting of 75 dB and 90 dB sound pressure data is analyzed, and the value of S with higher sound pressure in each group is 1. Simulator experiment results of analysis based on ordered logit model are shown in Table 3.

The analysis results in Section 3.2 of 6 designs (such as DN1, DN9, DN10, DN11, DN13, and DN17) are given in Table 3. Assume that the test of parallel lines in the first group is given by the following:

$$X^2_{60-75} = 14.751, \quad P_{60-75} = 0.255 > 0.05. \quad (5)$$

While the test of parallel lines in the second group is denoted by the following:

$$X^2_{75-90} = 11.279, \quad P_{75-90} = 0.505 > 0.05. \quad (6)$$

From above, it is clear that the coefficient of the regression model is the same as the test of parallel lines has passed, and it was appropriate to use the ordered logit model in each test. Let us assume that model by fitting information of the first group is as follows:

Table 3: Simulator experiment results of analysis based on the ordered logit model.

Test of parallel lines: $X^2_{60-75} = 14.751, P_{60-75} = 0.255$			
Model fitting information: $X^2_{60-75} = 67.513, P_{60-75} \leq 0.001$			
Variable	Estimate	Wald	Significance
$s_{60\text{-}75}$	−1.088	7.815	0.005
$w_{60\text{-}75}$	−0.522	1.871	0.171
$f_{60\text{-}75}$	−0.964	6.359	0.012
$b_{60\text{-}75}$	−2.102	27.036	0.000
Test of parallel lines: $X^2_{75-90} = 11.279, P_{75-90} = 0.505$			
Model fitting information: $X^2_{75-90} = 38.559, P_{75-90} \leq 0.001$			
Variable	Estimate	Wald	Significance
$s_{75\text{-}90}$	0.089	0.056	0.814
$w_{75\text{-}90}$	−0.495	1.698	0.193
$f_{75\text{-}90}$	−0.930	5.983	0.014
$b_{75\text{-}90}$	−2.051	26.280	0.000

$$X^2_{60-75} = 67.513, \quad P_{60-75} = 0.000 < 0.05. \quad (7)$$

While model fitting information of the second group is as follows:

$$X^2_{75-90} = 38.559, \quad P_{75-90} = 0.000 < 0.05. \quad (8)$$

Hence, this indicates that the analysis results have statistical significance, and the results derived should be valid.

The Bonferroni correction is a multiple-comparison correction that is employed when doing several dependent or independent statistical tests at the same time. So to correct the statistical errors of multiple hypothesis tests on a data set, we use Bonferroni correction. The experiment was carried out to check the significance within 95% confidence interval.

Significance should be less than $0.5/n$, where n is the number of tests, two tests for 60 dB and 75 dB, 75 dB and 90 dB were carried out here. The null hypothesis is rejected only if the significance is less than 0.025. In this case, $s_{60\text{-}75}$ $f_{60\text{-}75}$ $b_{60\text{-}75}$ $f_{75\text{-}90}$ and $b_{75\text{-}90}$ can observe statistically significant differences. It was considered that in our proposed cabin environment, sound pressure increased from 60 dB to 75 dB; symbol type and if recording broadcasting is added would have a significant impact on the function of ship fire alarm, but the impact of sound pressure increased from 75 dB to 90 dB; the waveform of alarm sound on its function is negligible.

3.4. Cabin Experiment. We use practice teaching at sea for cabin experiments. As shown in Figure 4, the top view of the cabin structure where the experiment is located is shown. The participant was trained in the central control room alone, and the fire alarm for testing was installed in the fixed position of the central control room. The normal walking time from the central control room to the fire station is about 1 minute. The experiment was called to end in five minutes after the time alarm triggered, and the experimental data were collected for the statistical record. Any participant who failed to return to the fire station would be asked the question, "if you want to return to the fire station but failed to do so for the difficulty of path finding," anyone with an affirmative response was considered to invalid data, and anyone with a denied response was further asked to answer the same three questions in Section 3.3 as in the simulator experiment. The work flow cabin experiment is shown in Figure 5.

Figure 5 shows work flow of proposed Cabin experiment, which starts from the trained participants by asking questions of Section 3.2. If any participant failed to answer the question in a minute, then he will begin the experiment. If the participant denies the response to a question, then another question will be asked from the questions mentioned in Section 3.2. After completing 5 minutes, the experiment is completed by generating the desired result.

For this experiment, we use formula (4) as the latent utility function, where the values and definitions of variables S, W, F, and B are the same as those in the simulator experiment and the data with a sound pressure of 60 dB and 75 dB constitute a group, and the data with a sound pressure of 75 dB and 90 dB form another group. We used an ordered logit model to analyze the two groups of data, and the analysis results are as in Table 4.

From the test of parallel lines and model fitting information in Table 4, we can see that it was appropriate to use the ordered logic expression in the two tests, and the results derived should be valid. The p value corrected by the Bonferroni correction is 0.025. By comparing the p value and significance, it can be concluded that the impact of sound pressure increased from 60 dB to 75 dB, symbol type and if recording broadcasting is added on the function of ship fire alarm is significant, and the impact of sound pressure increased from 75 dB to 90 dB, the waveform of alarm sound on its function is negligible.

3.5. Binomial Testing Experiment. The binomial test is used when a test has two potential results (for example, success/failure) and we have a thought regarding what the probability of accomplishment is. In simple words, a binomial test is used to determine whether observed test results differ from those predicted. Binomial testing is often used to assess the feature design of fire facilities. According to Section 3.2, DN9 is the most generic feature design for ship fire alarms under the IMO regulations. This is because it was designed with the static symbol, the sound pressure of 75 dB, with no broadcasting, continuous, and it can be placed in a bridge or any environment other than bridge. We have obtained 5 pairs of Binomial testing by using the most generic subject as a reference in pairwise comparison and coupled the other five typical designs mentioned in Section 3.2 with DN9.

During our Binomial Testing experiment, all the participants were asked to sit behind the bench by facing the screen. A volume-controlled loudspeaker was placed in front of the bench by recording the noise. This recorded noise from the cabin is looped back with the help of surrounding loudspeakers. After a pair of alarms was selected for the Binomial Testing experiment, the simulator screen captures of the scenes around two designs of fire alarms of the pairs were displayed on the left and right screen. Each participant can operate the left or right button on the bench to select the fire alarm sound on which screen will be played back and be asked to voluntarily select the options in the questionnaire. The questionnaire explicitly indicated that any or even all options may be unselected if it is impossible to identify strengths and weaknesses. Questions included in the questionnaire include the following:

Q1: which fire alarm detail design is easier to notice?

Q2: which fire alarm detail design can transmit the fire information more easily?

Q3: which fire alarm feature design more clearly prompts the "gather at fire station" information?

Q4: which fire alarm feature design makes you feel that the current situation is extremely urgent and immediate measures are needed?

Q5: as a whole, which fire alarm design is more suitable to transmit and urge the crew to deal with the fire?

From the above questions, it is cleared that Question-1 studies the sensory affordance of alarms. Question-2 and Question-3 study the cognitive affordance of alarms. Question-4 studies the functional affordance of alarms. Question-5 is a general problem. Question-1 to Question-4 are used to figure out which step exactly worked. Statistics of binomial test results are shown in Table 5.

As given in Table 5, 5 cycles of Binomial Testing were performed for pairwise comparison. After Bonferroni correction was used, The p value corrected by the Bonferroni correction is 0.01, and the null hypothesis can be rejected only when significance is less than 0.1. From a statistical point of view, replacing static symbols with flashing symbols had a significant impact on the function of a ship fire alarm by increasing sensory affordance and Functional Affordance.

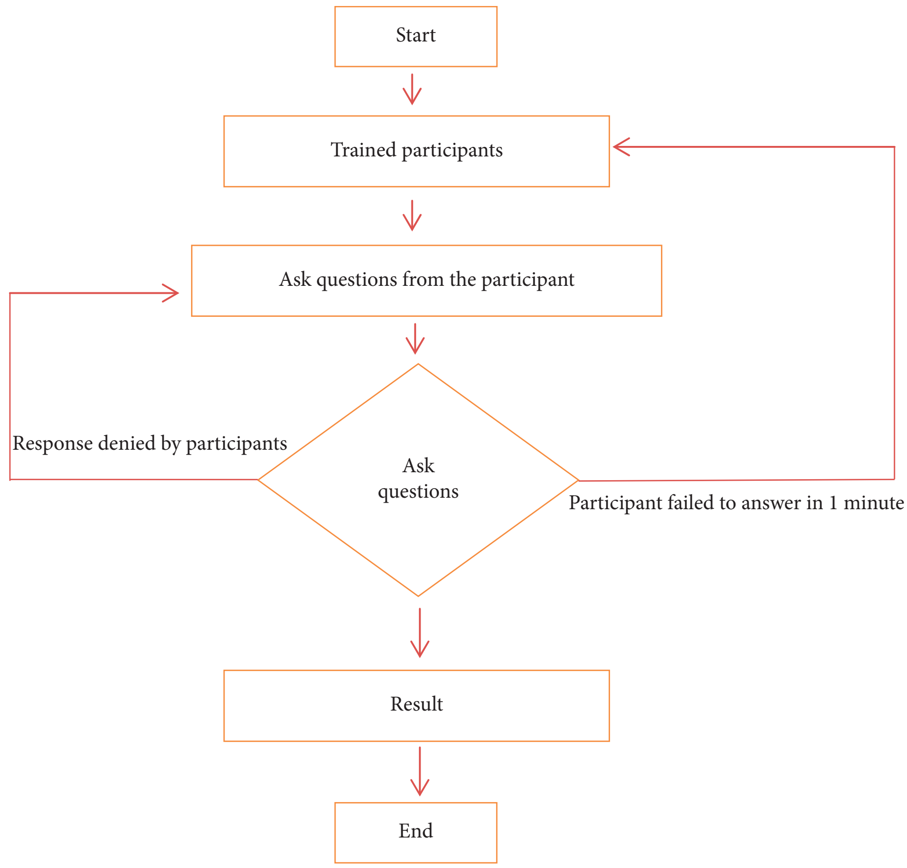

FIGURE 5: Flowchart of the cabin experiment.

TABLE 4: Cabin experiment results of analysis based on the ordered logit model.

Variable	Estimate	Wald	Significance
Test of parallel lines: $X^2_{60-75} = 13.871, P_{60-75} = 0.309$			
Model fitting information: $X^2_{60-75} = 47.266, P_{60-75} \leq 0.001$			
$s_{60\text{-}75}$	−1.383	6.200	0.013
$w_{60\text{-}75}$	−0.802	2.206	0.138
$f_{60\text{-}75}$	−1.373	6.514	0.011
$v_{60\text{-}75}$	−2.249	16.135	0.000
Test of parallel lines: $X^2_{75-90} = 9.170, P_{75-90} = 0.688$			
Model fitting information: $X^2_{75-90} = 23.727, P_{75-90} \leq 0.001$			
Variable	Estimate	Wald	Significance
$s_{75\text{-}90}$	0.053	0.010	0.919
$w_{75\text{-}90}$	−0.734	1.894	0.169
$f_{75\text{-}90}$	−1.293	5.937	0.015
$v_{75\text{-}90}$	−2.160	15.372	0.000

Sound pressure increased from 60 dB to 90 dB enhances the sensory affordance of the alarm to capture attention. Recorded broadcasting enhances the function of the fire alarm by increasing sensory affordance, Cognitive Affordance, and Functional Affordance. After the continuous alarm was changed to a 1 Hz pulse alarm, the significance of Question-4 is 0.008. The change of the waveform of alarm was considered to have a significant impact on the Functional Affordance of the fire alarm. However, the significance of Question-5 is 0.065, which merely indicates that change of waveform enhanced the general function of a fire alarm to a certain extent, but it was not considered as statistically significant.

In this part, we clarify the general status of the proposed scheme for ship fire alarm system, as we realize that the general status is quite possibly the most instructive boundaries in the results of the tests as it is anything but an overall image of the state of the ship alarm system, including three situations, such as normal, caution, and alarm; thus, Figure 6 shows the comparison of the proposed ship fire alarm system (from 2015 to 2020) for normal, caution, and alarm. Where the Normal status shows the test is inside the commonplace qualities, while caution and alarm could demonstrate that the threshold values (for first gathering 60 dB and 75 dB sound pressing factor information and for second gathering 75 dB and 90 dB sound pressing factor information) exceeded, or that the sample taken was not considerable, among different reasons; hence, further examination is needed from the ship alarm system staff as a potential issue could emerge from these situations.

4. Discussion

This paper presents a method to assess the fire alarm features by using the machinery operation simulator and theory of affordances. The same subjects were involved in the

Table 5: Statistics of binomial test results.

Category	Question-1			Question-2			Question-3			Question-4			Question-5		
	N	*C*	*S*	*N*	*C*	*S*	*N*	*C*	*S*	*N*	*C*	*S*	*N*	*C*	*S*
Test1															
DL1	0	0	0.000	0	Null	Null	0	Null	Null	0	Null	Null	0	0	0.000
DL9	33	100		0	Null		0	Null		0	Null		33	100	
Test2															
DL9	0	0	0.000	0	0	0.000	0	0	0.000	0	0	0.000	0	0	0.000
DL10	26	100		31	100		31	100		24	100		36	100	
Test3															
DL9	0	0	0.000	0	0	0.125	0	0	0.500	0	0	0.002	0	0	0.000
DL11	29	100		4	100		2	100		10	100		32	100	
Test4															
DL9	2	22	0.180	0	0	Null	0	Null	Null	0	0	0.008	2	18	0.065
DL13	7	78		1	100		0	Null		8	100		9	82	
Test5															
DL9	0	0	0.000	0	Null	Null	0	Null	Null	0	0	Null	0	0	0.000
DL17	35	100		0	Null		0	Null		1	100		35	100	

N = number of options, *C* = percentage of options, and *S* = significance.

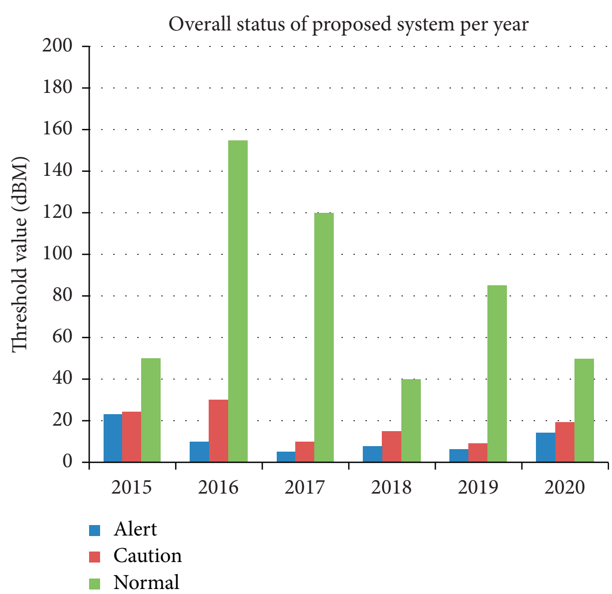

Figure 6: Overall performance from 2015 to 2020.

experiment process using cabin experiment and conventional Binomial Testing. It was found that the results obtained from the simulator experiment and that from the cabin experiment are in substantial agreement, but the results obtained from Binomial Testing are slightly different from those from the simulator experiment and the cabin experiment.

The results of three experiments indicated that the sound pressure increased from 60 dB to 75 dB and replacing static signs with dynamic signs can significantly enhance the function of fire alarm under the noise environment in a cabin, which agrees with the conclusion drawn in the study of dissuasive exit signage. The addition of recorded broadcasting also significantly improves the affordances of the ship fire alarm. Previous works reported that the evacuation effect of adding broadcasting is better due to higher reliability.

For fire alarm waveform, it is allowed to use a continuous alarm or 0.5 Hz–2.0 Hz pulse alarm in Resolution A.1021 (26). In this regard, the alarm sound from continuous alarm to 1 Hz square wave alarm was compared through three experiments. The significance value of the impact of a waveform on the function of a ship fire alarm is small (0.065~0.193), but this only means that a pulsing alarm can further enhance the function of a fire alarm compared with a continuous alarm. Since the null hypothesis cannot be rejected, we cannot statistically identify the significant effect of replacing continuous alarm with pulse alarm. Therefore, it is feasible to use the sound modes of ship fire alarm under two regulations as stated above.

According to the statistical results concerning the sound, pressure increased from 75 dB to 90 dB; the significance of the simulator experiment and the cabin experiment is much higher than the *p*value. According to the results of Binomial Testing, the null hypothesis is rejected and it is considered as a significant impact factor, which can be attributed to the difference between the three experiment procedures. The simulator experiment and cabin experiment are intended to experiment with or rate the design of a single fire alarm, while Binomial Testing is intended to compare the strengths and weaknesses as to the design of two fire alarms under a scene, so we took it for granted that a design with intense senses (e.g., high volume and brightness) should be better, but the impact of alarm sound pressure on fire alarm has an auditory threshold. Relevant research on fire alarms suggests that a volume change under the auditory threshold has a significant impact on alarm function, but a change beyond the auditory threshold has a slight impact on alarm function.

The comparison of results affirmed that it is feasible to assess the function of the fire alarm through the simulator experiment. However, some deficiencies were still found during the experiment. Firstly, all experiments were carried out under the same noise environment, without considering a quiet environment. Because the ship fire alarm was the intended object of this experiment, it is usually installed in a relatively noisy working environment. Secondly, participants were screened by a fixed standard: male interns who passed the CCS English test for general seafarers and obtained certificates of professional training for seafarers, with normal vision and auditory ability. This makes the difference between participants in each group of experiments very small, which is conducive to shielding the impact of interference factor on the results of qualitative analysis. The impact of noise environment and individual differences will be further discussed in subsequent works.

5. Conclusions

In this paper, the DMS-2017B machinery operation simulator coupled with the theory of affordances was proposed as a method to assess the design feature of a ship fire alarm. Compared with the cabin experiment, the simulator experiment can unify the noise environment to avoid the influence of environmental differences on the experimental results. In addition, the simulator experiment can also simulate the disaster scene in the real experiment to avoid personal injury of the participants. To assess all sorts of alarms installed on marine vehicles and the feature design of navigation, machine control, and other devices that transmit information by the auditory and visual function, we have used the HMI function. Furthermore, the HMI experiment is carried out on land fire as well as on fire-extinguishing facilities. A well-designed ship fire alarm can improve the efficiency of handling accidents and evacuation and, in turn, increase the survival rate. The method proposed in this study will be the starting point for assessing the feature design of the alarm, and the experimental data will be referenced for the design of the ship fire alarm. For the future, we have planned to design an intelligent ship alarm system with wireless capability. In addition, we have planned to address the issues and attacks related to the ship fire alarm system along with explaining new techniques that enhance the efficiency of the ship fire alarm system.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

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Research Article

Applied Research on InSAR and GPS Data Fusion in Deformation Monitoring

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With the enrichment of land subsidence monitoring means, data fusion of multisource land subsidence data has gradually become a research hotspot. The Interferometry Synthetic Aperture Radar (InSAR) is a potential Earth observation approach, and it has been verified to have a variety of applications in measuring ground movement, urban subsidence, and landslides but similar to Global Positioning System (GPS). The InSAR observation accuracy and measurements are affected by the tropospheric delay error as well as by the Earth's ionospheric and tropospheric layers. In order to rectify the InSAR result, there is a need to interpolate the GPS-derived tropospheric delay. Keeping in view of the above, this research study has presented an improved Inverse Distance Weighting (IIDW) interpolation method based on Inverse Distance Weighting (IDW) interpolation by using Sentinel-1 radar satellite image provided by European Space Agency (ESA) and the measured data from the Continuously Operating Reference Stations (CORS) provided by the Survey and Mapping Office of the Lands Department of Hong Kong. Furthermore, the corrected differential tropospheric delay correction is used to correct the InSAR image. The experimental results show that the correction of tropospheric delay by IIDW interpolation not only improves the accuracy of Differential Interferometry Synthetic Aperture Radar (D-InSAR) but also provides a new idea for the solution of InSAR and GPS data fusion.

1. Introduction

Synthetic Aperture Radar (SAR) is coherent active microwave remotely sensing equipment [1–3] that has been well recognized for its capacity to effectively record the scattering properties of the ground atmosphere [4–6]. A SAR sensor, which has a side-looking light orientation and can precisely extract the position of an item related to the location of the platform in which the sensor is installed, can be deployed on board an aircraft or satellite. The acquired geometry and the physical features of the imaged section lead to the creation of the obtained scattering radar signal, which, when correctly processed, results in the rebuilding of a complicated-valued high-resolution microwave picture of the surrounding area [2]. Interferometry Synthetic Aperture Radar (InSAR) is a wonderful platform for topographic and ground surface deformation imaging because of its entire-weather and day-to-night imaging ability, wide-ranging geographical cover, high resolution, and measurement accuracy [7–11]. The phase latency that occurs when radio signals travel through the atmosphere is a key source of error in repeat-permit InSAR [12–14], and it can be decreased using GPS techniques. But the three-dimensional resolution of GPS, on the other hand, is poor.

In order to fix the InSAR tropospheric delay inaccuracy on a pixel-wise basis, the GPS-derived tropospheric delay should be adjusted. In most cases, tropospheric delay correction is affected not just by alterations in horizontal distance but also by variations in height. The influence of height on tropospheric delay has not been completely studied in standard Inverse Distance Weighting (IDW) interpolation. In this study, an effective aspect for the IDW is created, which is referred to as improved IDW (IIDW). For this experiment, we have used Sentinel-1 satellite images from

August 20, 2016, to September 25, 2016, given by ESA, as well as measured data from the CORS provided by the Survey and Mapping Office of the Hong Kong Lands Department. We have also investigated D-InSAR results qualitatively as well as quantitatively in our experiments. After correcting for atmospheric delay, the deformation values in most areas of Hong Kong during the studied time period were between −1.75 mm and 1.71 mm, which were more consistent with actual subsidence in the study area and provided accurate data support for ground subsidence monitoring and forecasting.

The remainder of this paper is organized as follows: In Section 2, we discuss the related works of researchers; in Section 3, we explain our proposed work; in Section 4, the experimental work of our proposed system is discussed; and, finally, conclusion is presented in Section 5.

2. Related Work

The Global Positioning System (GPS) and Interferometry Synthetic Aperture Radar (InSAR) are effective methods for obtaining topography and Earth's surface movement for Earth's crust deformation research [12, 13]. According to [14], each of these methods is based on the principle of properly calculating the transit time of an electromagnetic signal generated by satellites orbiting high above the Earth's surface. The authors in [15] investigated that electromagnetic signals are slowed and propagation speed is slowed as they pass through the troposphere. The degree of latency is principally determined by the geographically and temporally varying temperature and pressure of the atmosphere's constituent gases, particularly water vapour, and causes major mistakes in repeat-pass InSAR observations. According to [16], significant research has been conducted in the last two centuries in order to better understand and reduce tropospheric influences incorporated into InSAR observations.

According to the researchers of [12], a 20% variation in relative humidity in space or time could cause 10 cm of inaccuracies in deformation results. Furthermore, adjusting for low stratification tropospheric latencies can improve unwrapping dramatically over rugged terrain where the interferometric phase may be aliased [17]. Tropospheric impacts in InSAR images can be reduced using two different approaches, according to the authors in [18]: empirical, which is focused on direct projections of the raw InSAR phase delay information, and predictive, which is premised on exterior sets of data such as GPS, climate models, or satellite photos. Tropospheric impacts in InSAR images are decreased using the first method, which involves averaging many separate interferograms. The tropospheric delays are handled as bright lights in [18], which is acceptable if there is no association between topography and tropospheric delay or if the InSAR collection equally samples the time dynamics of the deformation. Using the reverse wavelet transform, the authors in [19] rectified the topographical linked parts by downweighting detected related coefficients, which reflected the impact of the atmospheric delay. The ionospheric impact on InSAR signals impacts both azimuth subpixel offsets and differential interferograms, according to the authors in [20]. The first bias is created by directional changes in azimuth pixels' relative subpixel location, while the second bias is caused by comparative lengthening of wave pathways across two InSAR collections, which affects the interferogram image. Inspired from the above works, this research study aims to develop an improved IDW interpolation method based on IDW interpolation by using Sentinel-1 radar satellite image provided by ESA and the measured data from the CORS provided by the Survey and Mapping Office of the Lands Department of Hong Kong.

3. Proposed System

In this section, we will explain our proposed research work on InSAR and GPS data fusion in deformation monitoring; at the beginning, we will give an overview of Global Positioning System (GPS) and Interferometry Synthetic Aperture Radar (InSAR) along with their connection to each other. After that, we will explain the InSAR and GPS data fusion process using a diagram (Figure 1). Finally, we will compare two-difference algorithms, Inverse Distance Weighting (IDW) and our proposed improved Inverse Distance Weighting (IIDW), for tropospheric delay correction.

Level measurement is one of the most important means to monitor ground subsidence and it has attracted great attention these days. With the continuous progress of science and technology, in recent years, the means of ground settlement monitoring has been enriched, with the emergence of Global Positioning System (GPS), Interferometry Synthetic Aperture Radar (InSAR), etc. Due to the inherent characteristics of radar measurement, the InSAR technology is incomparable to other methods by virtue of its advantages of all-day, all-weather ability, spatial continuity, high accuracy, and contactlessness [21]. On other hand, the GPS technology can accurately determine tropospheric and ionospheric delays and achieve high accuracy positioning at the same time. Therefore, data fusion of InSAR and GPS data can not only correct the satellite orbit errors and atmospheric delay errors that are difficult to be eliminated by InSAR data itself but also realize the effective unification of high spatial resolution and high-range deformation accuracy of InSAR technology and high temporal resolution and high plane position accuracy of GPS technology [22–26].

GPS can obtain single-point continuous high-precision plane position data, while InSAR can provide higher-precision wide-range monitoring results for vertical ground deformation. Therefore, the fusion of GPS data and InSAR data can realize the effective combination of high spatial resolution and high elevation deformation accuracy of InSAR technology and high temporal resolution and high planar position accuracy of GPS and correct the errors that are difficult to be eliminated by InSAR data itself. With the purpose of studying the fusion of InSAR and multisource data, GPS is used to correct the atmospheric delay error of InSAR to better reflect the subsidence pattern of the ground subsidence region [27].

3.1. InSAR and GPS Data Fusion. InSAR (Interferometry with Synthetic Aperture Radar) is a technology that derives ground height and distortion information using phase's information extracted from Synthetic Aperture Radar

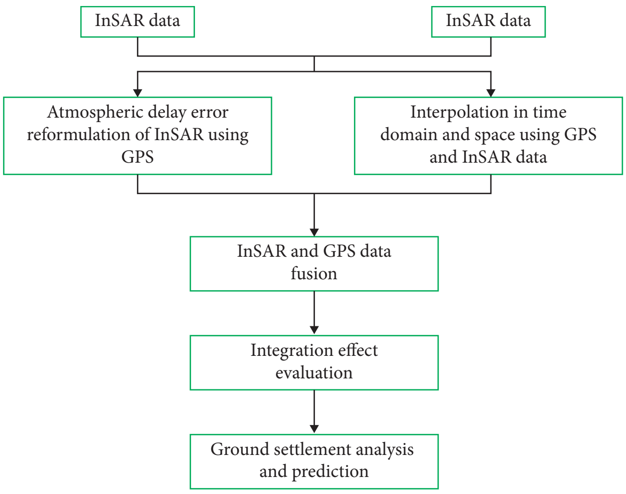

Figure 1: Flow chart of InSAR and GPS data fusion.

multiple data. Differential Interferometry Synthetic Aperture Radar (D-InSAR) is based on InSAR, and its theoretical precision when used in subsurface deformation monitoring can reach subcentimeter levels. The rest of this section will debate on the process of InSAR along with GPS data fusion and tropospheric delay correction techniques.

3.2. InSAR and GPS Data Fusion Process. The study of InSAR and GPS data fusion for ground settlement monitoring is proposed based on a thorough collection, review, and analysis of related literature. During the process of InSAR and GPS data fusion, in our proposed system, we have used GPS data in order to correct the atmospheric delay error of D-InSAR results; after that, this GPS data is used to accurately determine the satellite orbit parameters, and, finally, the fusion effect is evaluated, and further ground subsidence is analyzed and predicted. The main technical process is shown in Figure 1.

3.3. Two-Difference Algorithm for Tropospheric Delay Correction. For tropospheric delay correction, assume that point A on the SAR image is fixed and B is another point on top of the SAR image. Assuming that the atmospheric delay of point A at SAR image j estimated from GPS is D_A^j and the atmospheric delay of point B at SAR image j is D_B^j, the delay difference between the two stations can be obtained as

$$D_{AB}^j = D_B^j - D_A^j. \tag{1}$$

With point A as the fixed reference point, the single differential delay between other GPS points and point A can be solved according to the above equation, and then the obtained single differential delay is interpolated to obtain the atmospheric delay correction image map.

Consider two sites A and B while assuming two times j (primary image) and k (secondary image); two single-difference scores can be calculated from equation (1):

$$\begin{aligned} D_{AB}^j &= D_B^j - D_A^j, \\ D_{AB}^k &= D_B^k - D_A^k. \end{aligned} \tag{2}$$

The two single-difference results are further differenced once again, that is, double-differenced.

$$\begin{aligned} D_{AB}^{jk} &= D_{AB}^k - D_{AB}^j \\ &= \left(D_B^k - D_A^k\right) - \left(D_B^j - D_A^j\right) \\ &= \left(D_B^k - D_B^j\right) - \left(D_A^j - D_A^j\right). \end{aligned} \tag{3}$$

3.4. Interpolation Model for Tropospheric Delay Correction. The station spacing of GPS networks is generally tens or even hundreds of kilometers, which causes the spatial resolution of the GPS-acquired atmospheric delay correction to be unable to meet the interpolation requirements of InSAR imagery. The atmospheric delay correction obtained by processing GPS needs to be encrypted and interpolated to further provide effective atmospheric delay correction for InSAR images [28–30]. There are two main types of interpolation methods: random and deterministic.

3.4.1. Kriging Interpolation. Kriging, commonly known as Gaussian process regression, is a geostatistical interpolation technique. Interpolated values are represented using a Gaussian process guided by previous covariance matrix in Kriging. Kriging is a technique for predicting values in a particular region.

Assuming that there are n known points in the desired interpolation region, a linear combination can be used to obtain an estimate of any point in the desired interpolation region:

$$Z_v^* = \sum_{i=1}^{n} \lambda_i Z\left(x_i\right). \tag{4}$$

In equation (5), $Z(x_i)$ is the value of the known points, and the weighting factor is denoted by the weighting factor, which shows the influence of the known points on the points to be estimated.

The Kriging interpolation method stipulates that the estimated value of any point in the interpolation area and its true value have the following relationship under unbiased conditions:

$$\begin{aligned} E\left[Z_v^* - Z_v\right] &= 0, \\ E\left[Z_v^*\right] &= E\left[\sum_{i=1}^{n} \lambda_i Z\left(x_i\right)\right] \\ &= \sum_{i=1}^{n} \lambda_i E\left[Z\left(x_i\right)\right] = E\left[Z_v\right] = m, \end{aligned} \tag{5}$$

where m is the mathematical expectation.

Because

$$E\left[Z\left(x_i\right)\right] = m, \tag{6}$$

it results in

$$\sum_{i=1}^{n} \lambda_i = 1. \tag{7}$$

Kriging's interpolation method specifies that the estimation variance minimization condition should be satisfied in the solution process as follows:

$$E\left\{\left[Z_v^* - Z_v\right]^2\right\} = \min. \tag{8}$$

The equation for the variance in the solution is

$$\begin{aligned}\sigma_E^2 = E\left\{\left[Z_v^* - Z_v\right]^2\right\} &= \sum_{i=0}^{n}\sum_{j=0}^{n}\lambda_i\lambda_j C\left(x_i, x_j\right) \\ &= C\left(x_0, x_0\right) - 2\sum_{j=1}^{n}\lambda_i C\left(x_0, x_j\right) \\ &\quad + \sum_{i=0}^{n}\sum_{j=0}^{n}\lambda_i\lambda_j C\left(x_i, x_j\right).\end{aligned} \tag{9}$$

In equation (9), $C(x_i, x_j)$ is the covariance function of x_i and x_j.

The computational process of Kriging interpolation is very simple and the implementation process mainly includes statistical analysis of data, simulation of variorums, creation of surfaces, and detection of surface changes [31].

3.4.2. Inverse Distance Weighting (IDW) Interpolation. Inverse Distance Weighting (IDW) is based on the principle that each known point in the region to be interpolated has a local influence, which becomes smaller as the distance increases. Observations closer to the unmeasured point have more influence on the unmeasured point than observations farther away from the unmeasured point, and the magnitude of the influence is expressed in terms of weights, with the weights of points closer to the expected point being larger than the weights of points farther away from the expected point.

IDW equation for the atmospheric delay obtained from GPS observations is

$$\widehat{D}\left(\lambda_0, \phi_0\right) = \sum_{i=1}^{N} w_i D\left(\lambda_i, \phi_i\right). \tag{10}$$

In equation (10), the interpolated atmospheric delay at the point with coordinates East λ_0 and North ϕ_0 is $\widehat{D}(\lambda_0, \phi_0)$.

The GPS delay correction at the point with coordinates East λ_0 and North ϕ_0 is $D(\lambda_i, \phi_i)$.

The weights of IDW are

$$w_i = \frac{d_{i0}^{-P}}{\sum_{i=1}^{N} d_{i0}^{-P}}, \tag{11}$$

where w_i denotes the weight related to the delay of GPS acquisition. The number of GPS points near the expected point used for interpolation is denoted by N. The interpolated weights become smaller as the distance increases.

$$\sum_{i=1}^{N} w_i = 1, \tag{12}$$

where $d_{i0} = \sqrt{\left(x_0 - x_2\right)^2 + \left(y_0 - y_2\right)^2 + \left(z_0 - z_2\right)^2}$.

In equation (12), the distance from the sample point i to the point to be interpolated is $d_{i0} = (i = 1, 2, \ldots, N)$ and P is the power parameter.

3.4.3. Improved Inverse Distance Weighting (IIDW) Interpolation. From the principle of IDW, it is clear that the IDW interpolation method treats the horizontal distance and elevation difference between the data points and the points to be interpolated to the same degree of influence on the points to be interpolated. This is an ideal state, which does not correspond to the actual situation. In order to better simulate the most realistic situation for interpolation, it is necessary to differentiate the influence of the horizontal distance and elevation difference on the interpolation points. Based on the above IDW principle, an influence factor α is introduced; that is, equation (12) is rewritten as

$$d_{i0} = \frac{\sqrt{\left(\alpha d_{i0}^s\right)^2 + \left((1-\alpha) d_{i0}^h\right)^2}}{\alpha}, \tag{13}$$

where $d_{i0}^s = \sqrt{\left(x_0 - x_2\right)^2 + \left(y_0 - y_2\right)^2}$ is the horizontal distance from the data point to the point to be interpolated; the difference in elevation between data point i and the interpolated point is denoted by $d_{i0}^h = h_i - h_0\,(i = 1, 2, \ldots, N)$.

Therefore,

$$\begin{aligned}\widehat{D}\left(\lambda_0, \phi_0\right) &= \sum_{i=1}^{N} w_i D\left(\lambda_i, \phi_i\right), \\ w_i &= \frac{d_{i0}^{-P}}{\sum_{i=1}^{N} d_{i0}^{-P}}, \\ \sum_{i=1}^{N} w_i &= 1,\end{aligned} \tag{14}$$

where $d_{i0} = \sqrt{(\alpha d_{i0}^s)^2 + ((1-\alpha) d_{i0}^h)^2}/\alpha$.

These three equations constitute the improved Inverse Distance Weighting (IIDW) method. The influence factor can be determined by achieving the optimal interpolation accuracy through multiple trials.

4. Experimental Work

For experimental work, we have used cross validation technique, wherein 36 days' session data observed from August 20, 2016 to September 25, 2016 by the Survey and Mapping Office of the Lands Department of Hong Kong were used to investigate the efficiency of the proposed IIDW. Out of 18 stations, 17 stations were considered as measured locations and the remaining one was used as prediction location for determining the tropospheric delay correction and comparison with its GPS-derived delay. This process is repeated until all tropospheric delays of 18 stations were predicted and compared with their GPS-derived delays. Figure 2 shows the heights and locations of the GPS sites for this experiment.

4.1. GPS Actual Measurement Data Processing. The "Hong Kong Satellite Positioning Reference Station Network" of the Survey and Mapping Office of the Hong Kong Lands Department, SatRef, consists of 18 continuously operating CORS evenly distributed throughout Hong Kong, as shown in Figure 3.

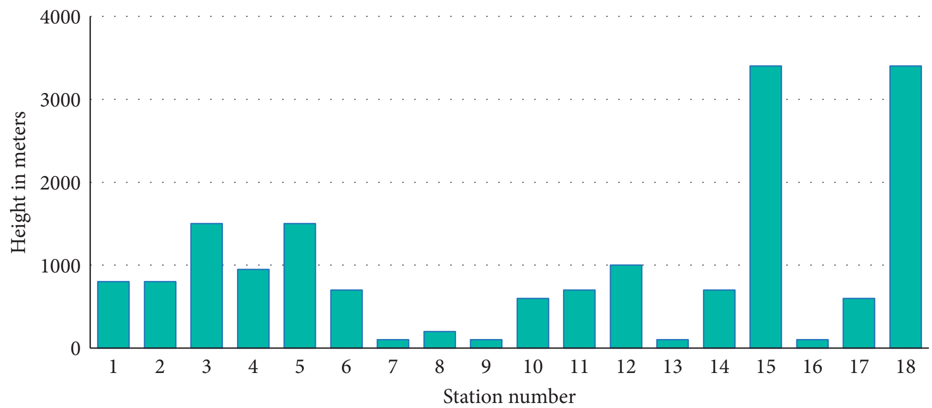

Figure 2: Heights of the GPS site.

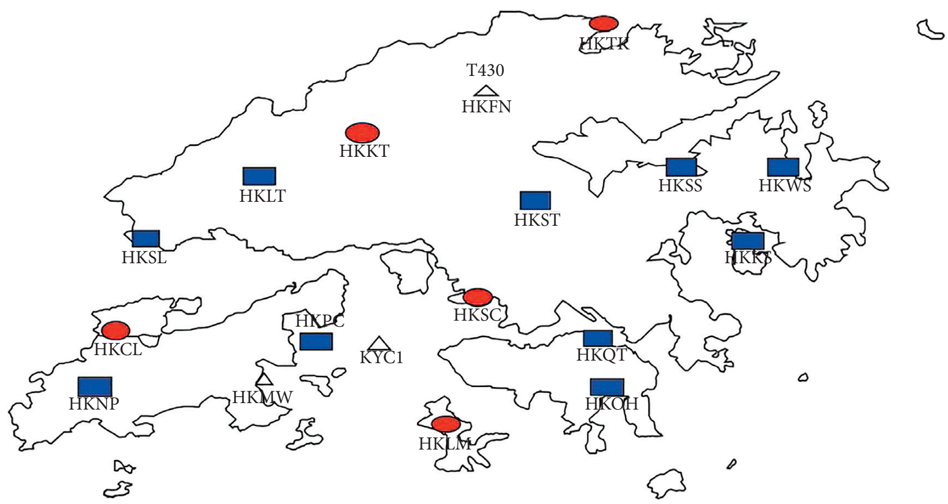

Figure 3: Distribution map of the measured stations of the CORS.

Among the 18 sites in the SatRef system, the monitoring data of the sites with gaps were removed because there were gaps in the data of one or two sites. Ten of these sites were selected as GPS observation sites (blue rectangular points in Figure 3) and five sites were selected as predicted sites for tropospheric delay correction (red circular points in Figure 3). The significance of the predicted sites is that the predicted values can be compared with the measured values obtained by solving these sites.

GPS observations were made during one hour before and after the radar satellite pass in the study area with a sampling interval of 30 s. Two days of observations from the SatRef system were used for data processing with the GAMIT software. During the data processing, the tropospheric delay correction of the station was set to a 30 min interval, so that there were a total of four tropospheric correction parameters in the data processing. In this experiment, the Sha Tin (HKST) station is set as the reference point, and it is assumed that it remains unchanged. Based on this station as the reference, the single-difference tropospheric correction of other stations with this point is further calculated. This requires another differential on top of the single differential in the previous step to satisfy the tropospheric delay correction of the InSAR image, that is, double differential. This results in the double-differential tropospheric delay correction of InSAR images. The double-difference results for most stations are smaller than the single-difference results, and the results of double-difference range from −5.02 cm to 5.34 cm, and this correction is of great importance for D-InSAR to obtain subcentimeter-level accuracy.

Three different interpolation methods, namely, Kriging, IDW, and IIDW interpolation methods, are selected to interpolate the double-difference results, and the IIDW interpolation method yields a plot of the double-difference results, as shown in Figure 4, and the obtained results can be directly corrected for the convective layer delay of the D-InSAR data.

4.2. Sentinel-1 Satellite Measured Data Processing. Sentinel-1 satellite images from August 20, 2016, to September 25, 2016, were selected for the experimental data. The deformation image pair time interval was 36 days and interferometry was performed on the two images using the D-InSAR method.

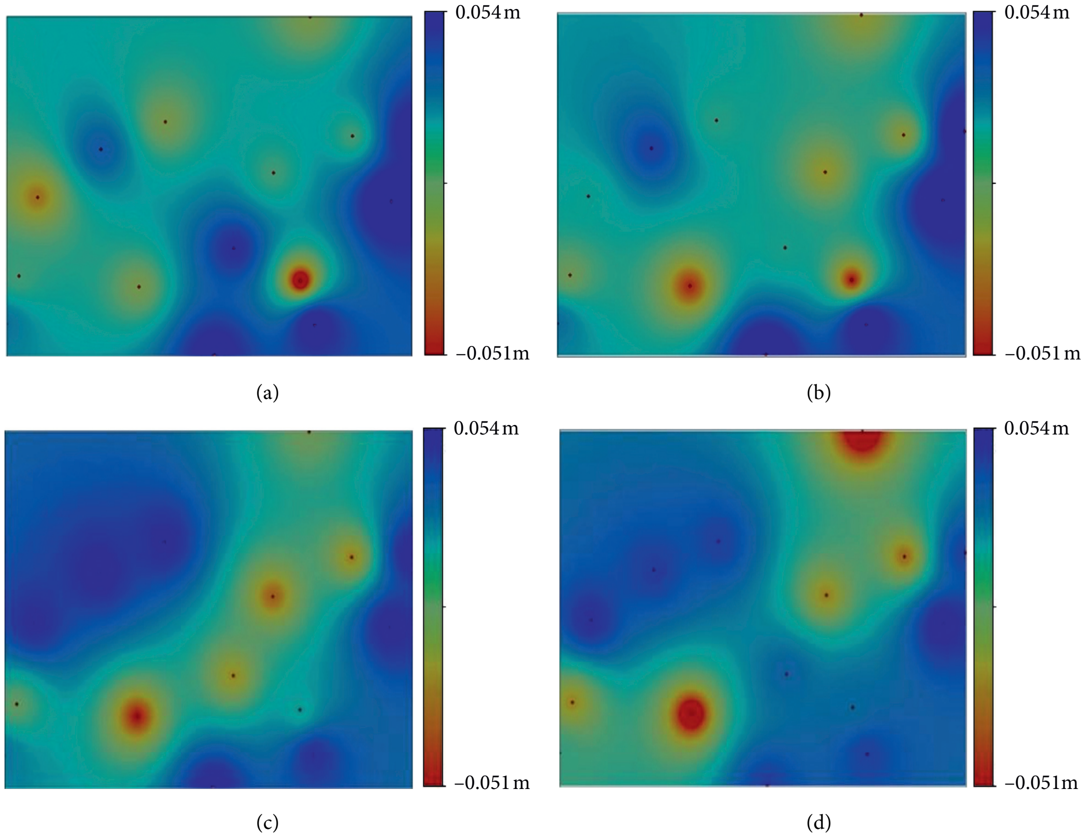

Figure 4: Interpolation of IIDW. (a) 30 min. (b) 60 min. (c) 90 min. (d) 120 min.

The baseline estimation is performed first, followed by the interferogram generation, the filtering and correlation calculations are performed after getting the processing results of the previous step, the filtered interferogram and coherence coefficient map are obtained, the phase deconvolution processing is performed in the next step, followed by the phase transformation as well as the geocoding, and the final deformation data can be obtained through the above steps, as shown in Figures 5 and 6.

The subsidence map of the test area was obtained by D-InSAR data processing technique and combined with GIS technology. From Figures 5 and 6, it can be seen that the maximum subsidence value of the ground surface before the atmospheric delay correction is 3.85 mm and the maximum uplift value is 11.98 mm, and the maximum subsidence value of the ground surface after the atmospheric delay correction is 4.02 mm and the maximum uplift value is 10.07 mm. From Figure 6, it can be seen that the subsidence changes in most areas of the study area are small after the atmospheric delay correction, and it can be combined with the approximate location; and extent of ground subsidence in the studied area can be obtained by combining the geographic location map of the study area. In the study area, some areas show some minor subsidence, some areas form "funnel-shaped subsidence," and some areas experience uplift. In the study area covered by the radar images, there are mainly two obvious subsidence targets. One of them is located in the northeast of the image in Tai Po, Luohu, and Yantian districts, reaching a maximum subsidence value of 4 mm; the other is located in the southwest of the image in the island, reaching a maximum uplift value of 10 mm, which may be caused by land reclamation. D-InSAR results before atmospheric delay corrections of test area are shown in Figure 5. D-InSAR results after atmospheric delay corrections of test area are shown in Figure 6.

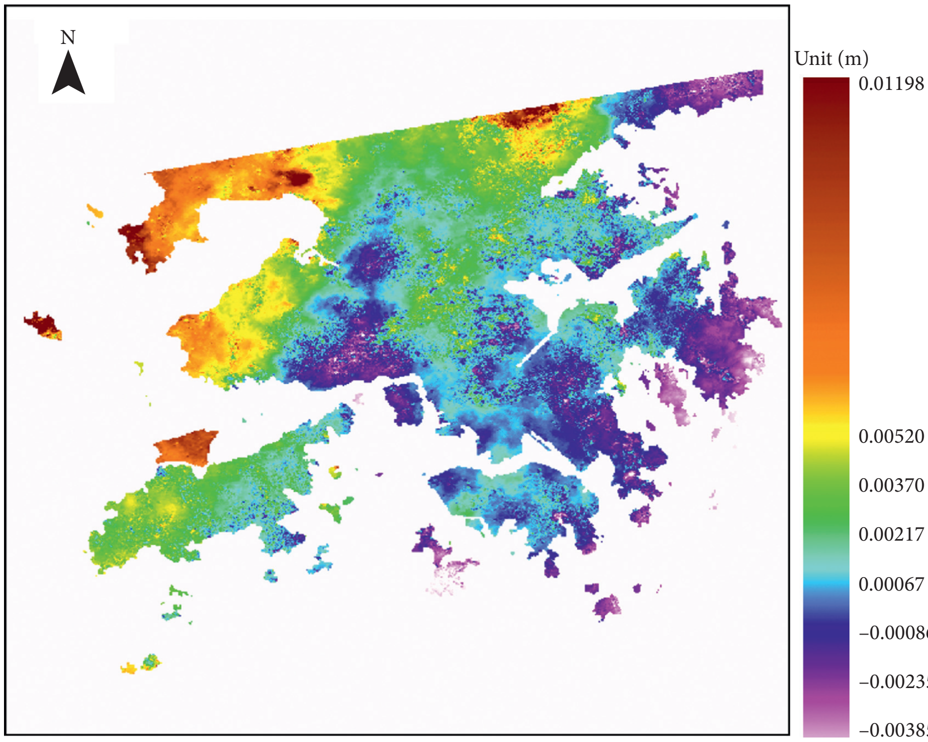

Figure 5: D-InSAR results before atmospheric delay corrections of the test area.

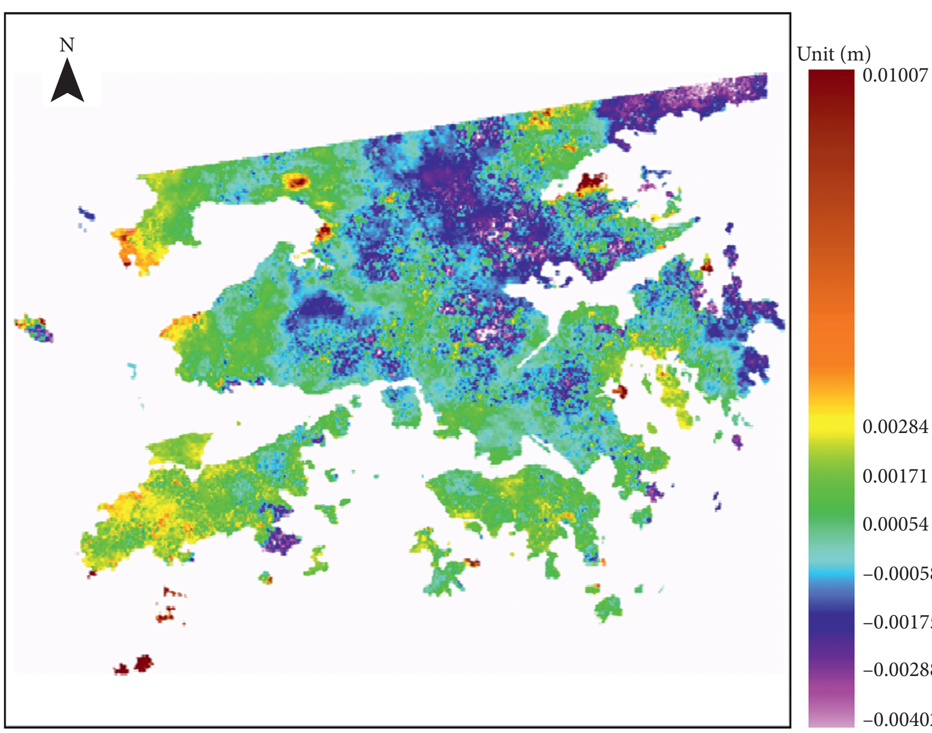

Figure 6: D-InSAR results after atmospheric delay corrections of the test area.

5. Conclusion

This research work puts forward an improved Inverse Distance Weighting (IIDW) interpolation method based on traditional Inverse Distance Weighting (IDW) interpolation method for InSAR and GPS data fusion in deformation monitoring. The Inverse Distance Weighting (IDW) interpolation method does not fully consider the effect of height on tropospheric delay, so we have analyzed the influence of atmospheric delay on InSAR, where the differential model of atmospheric delay correction is studied, and the InSAR data processing process based on GPS atmospheric delay correction is designed. Furthermore, GPS observation data and D-InSAR data were fused and studied by using GPS monitoring data from Hong Kong SatRef network and Sentinel-1 radar satellite monitoring data. Finally, the obtained D-InSAR measurements were analyzed qualitatively as well as quantitatively, where total tropospheric delay over the Hong Kong SatRef network stations was solved by using GAMIT software, and the difference maps of atmospheric delay were generated according to Kriging interpolation, IDW interpolation, and IIDW interpolation methods. The experimental results after atmospheric delay correction showed that the deformation values in most areas of Hong Kong were between −1.75 mm and 1.71 mm during the studied time period, which were more consistent with the actual subsidence in the study area and provided accurate data support for ground subsidence monitoring and forecasting.

Data Availability

The datasets used and/or analyzed in the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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Research Article

Research on Engineering Project Management Method Based on BIM Technology

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Construction projects require a significant amount of money and other resources in order to carry them out in an effective way. Cost control is a critical step in ensuring the success of the project and increasing its value. Nowadays, the large-scale application of BIM technology has ushered a technical change in the development of construction projects, which has greatly increased the level and efficiency of project management. Due to BIM technology, the construction engineering quality is significantly improved which really helped in obtaining the social and economic benefits. However, the BIM technology in our country is started relatively late and the technical force is not strong enough; then correspondingly, we must deal with many problems in the process of developing and using BIM technology based projects. In view of the fact and to address this issue, this paper establishes a three-dimensional architectural model based on the relevant information and data of the construction project using the BIM technology. The proposed model optimizes the clustering of construction project information data and adaptively configures the whole life cycle process of the construction projects. In addition, the performance of the proposed system has been compared and tested with the other systems as well which shows how good the proposed system is, as compared to the other systems. Further, the proposed model makes the artificial intelligence efficiency of the project management better. The simulation results show that the model not only has good access and query capabilities but also greatly improves the intelligence level of the project management.

1. Introduction

The 21st century is the era of technology and innovations. The use of smart technologies and developments in these technologies have made people's lives easier, facilitating every aspect of life such as healthcare, agriculture, industries, and construction projects. Regardless of the faster growth and development of the new technologies in the modern era, many underlying concerns, such as project delays, cost overruns, and low efficiency and performance, continue to plague construction projects [1]. The construction sector in China, as well as many other nations, has been criticized for having a large number of stakeholders, a long project cycle, a high level of risk and instability, a lack of coordination among construction stakeholders, and a lack of data exchange and resources integration [2, 3]. Most of the construction companies are suffering from a survival dilemma in today's construction business, as the market is growing saturated and the economy is bleak [4]. Nowadays, there is tough completion among the construction companies, and if a company wants to take its place in the high rank and get an advantage, it has to offer quality services at low price by reducing the cost of the company, and at the same time, it will give assurance of high-quality services. Similarly, the clients like those products that are of high quality and value in the market and have low prices. A construction project requires more resources for that it needs more funds, and using those resources and funds in an efficient way is one of the most important factors to determine the success of a project.

The demand and quality of a project, management level of the project, and the benefits associated with the project have been improved significantly due to the use of these technologies [5]. Scheduling of a task is considered as one of the most important aspects of a project in the modern project management systems and has a great impact on both the economic and social benefits of the engineering projects.

China's construction industry has achieved great success in recent years. As the intention of the construction projects, whole life management is necessary. Therefore, it is very important to find a suitable way to realize this purpose. Despite the continuous increase and updating in the architectural scale and complex construction problems, it is not possible for the numerous participants of a project involved in many large projects of project management to carry out the missing information and to integrate the information. Since the degree of information integration is very low, it becomes a big headache for the project manager to deal with all the participants of a project and the communication and coordination that takes place between the project participants. In addition, due to these issues, the organization pattern technology cannot meet the requirements of the construction of large projects. The emergence of the Building Information Model (BIM) had brought new opportunities to the whole life cycle of the management of construction projects. BIM is a process that involves the creation and administration of digital representations of physical and functional aspects of places and is backed by a variety of tools, technologies, and contracts. BIM has various applications in different fields such as visualization, fabrication, code reviews, cost estimation, construction sequencing, forensic analysis, facilities management, project management, collision, conflict, and interference detection. It introduces information technology into the whole life cycle of the project, unifies all stages of project management with digital means, and coordinates simulation and optimization through the realization of a visualization system. Professional and expert people figured out with the help of experiments that high-quality services cannot be achieved using the traditional project management functions and approaches, while the BIM technology helps in the effective coordination of the cooperated building parties' communication and achieved the high-quality services. Considering the present situation and the application of BIM at home and abroad, for the whole life cycle of project management, various research studies have been conducted [6].

With the start of urbanization, more and more construction projects come up, and for that there are needs of vital management policies for those projects. It is feasible to use BIM technology to manage the construction projects in an effective way [7]. Professor Chunk Eastman of Georgia Institute of Technology, "the Father of BIM," founded the idea of BIM. There are three periods which are significantly charming to the exploration of BIM technology: embryonic, generation, and development stages. In the process, the penetration and acceptance of the technology are increasing. The concept and technology contact of BIM in our country began after 2002. This technology was emphasized in the 11^{th} Five-Year Plan of our country and is considered as the most effective method to solve the optimization of construction schemes. Another prominent role of BIM technology in management of engineering projects is to improve the accuracy of the project. In the engineering project management practice, the improvement precision can strengthen the management from a more subtle angle, so the quality of management will be further improved. In the concrete use of BIM to create the database, and then through the existence of a 5D associated database, a great progress has been made in the performance of engineering, so the construction budget has been greatly improved. With the high level of engineering components, it is possible and effective for a management to afford information in time and preceding the information quickly [8]. In short, with the use of BIM technology, the accuracy calculation of the whole project is more reliable, and the management based on the precision calculation also realizes further optimization. On the basis of overall optimization, the improvement of management effect is obvious, which is the outstanding effect of the application of BIM technology in precision.

Jia et al. [9] stated that, due to the current schedule management problems of the project management companies, the project schedule is lagging behind, and combined with the cutting-edge research in the field of schedule management, a buffer-based approach to the whole process schedule management of the project is constructed. Both of the settings of the progress buffer and the deviation standard are included in our proposal and then are supervised by themselves. Thus, it can obtain a relatively better accuracy and enables that the project is completed to some extent. However, the accessibility and efficiency of this method are not strong. Paulman and Dirks [10] do really well in the management level and efficiency of teaching engineering projects in colleges and universities, based on the exploration and practices of Dalian University. Their study was mainly based on the detailed analysis of the user needs and business processes of teaching project management. They designed a teaching project management platform based on the web technology, and the information management of the project is recognized. It has effectively promoted the standardization and systematization of project management, improved work efficiency, and promoted the information construction of teaching management in the colleges and universities. In the process of large-scale construction, construction safety is the premise for effective project implementation, and safety management should be highly valued. Jin [11] collected the data of construction loss, analyzed the change trend of the safety accident, and then established the copy dynamic equation model of construction safety through the return matrix. They further discussed the necessity of the construction safety management in the Bureau and made the profit and loss balance analysis according to the evolutionary stabilization strategy of the people in the Bureau. The results show that, under the premise of maximizing interests, the players in the Bureau will choose the game strategy with the minimum loss. However, the method has limited access capability and limited application scope. The main contributions of the proposed study are listed below:

(i) This paper proposes an approach building a 3D learner to handle the effectiveness which takes BIM as a foundation by optimizing the scheduling and do cluster analysis of the overall data to improve the quality of construction projects over the entire life cycle.

(ii) The recognition model is applied to the adaptive configuration of construction projects, and a three-dimensional rendering method is used to construct a dynamic data analysis model for project management.

(iii) Using BIM technology to obtain the basic data will improve the level of project management.

(iv) Finally, various simulation experiments are conducted to verify the superiority of the method in optimizing the intelligentization of engineering project management.

The rest of the paper is organized as follows. Section 2 represents the BIM data analysis and database construction for construction project management and Section 3 shows the BIM technology optimization of engineering project management, while Section 4 illustrates the simulation results and experimental analysis. We conclude our paper in the last section, i.e., Section 5.

2. BIM Data Analysis and Database Construction for Construction Project Management

In the management of construction engineering, the BIM technology makes the original abstract management content through the model and then enables the manager to observe, analyze, research, and coordinate various management work from the holistic perspective to improve the quality of engineering information management [12]. In practical engineering management, the application of BIM has the following characteristics:

(i) *Analogue.* The simulative experiments, the simulation design of the buildings, and the things that cannot be operated in the simulated reality show the analogue characteristics of BIM technology, for example, the simulation of emergency evacuation and sunshine. In addition, in the process of cost control, BIM can be used to manage, so that the builders and the project side will get more economic benefits [13].

(ii) *Coordination.* In the construction project management, there will be problems that need each department to cooperate with each other. If the problem is difficult to solve immediately in the construction of the project, it is necessary to hold relevant meetings, organize a management staff to discuss the problem, point out the reason of the problem, and make an effective remedy [14, 15]. But there are some limitations in this way of dealing with problems. The emergence of BIM can make use of its coordination to arrange and lay out the building internal components reasonably and coordinate the elevator shaft construction and other constructions.

(iii) *Visibility.* Under the continuous development of the society, the architectural form is going to gradually diversify and becoming complicated with the passage of time. Under the requirements of modern construction, the traditional construction drawings have lost their value and appeared unsuitable nowadays. The construction form of the construction workers' own imagination will not only obstruct the smooth construction of the whole construction project, but also lead to the difficulties in construction and project management [16, 17]. The duration of the work is extended. After the appearance of BIM, it can be displayed to the three-dimensional solid objects of the building before the construction project begins and can also present the internal components of the building in front of people through the visual BIM. So, using BIM can guide the construction workers to smooth the construction. In addition, the construction workers can also share information resources with the other construction workers. Improving the efficiency of process management is of great significance.

(iv) *Optimization.* BIM can change the traditional management mode in the construction engineering management. A project manager can use the BIM technology to carry on the virtual construction, take the visualization and integrated 4D construction way, and achieve the effect of optimizing the construction management mode. In order to effectively connect the building information model and construction schedule, concentrating on the information of the construction resources and site layout, using the construction information model of the 4D effect will dynamically and centrally control the equipment information, cost information, human information, material information, and so on and can also visualize the construction process and realize the related personnel [18, 19]. The purpose of reasonable cooperation between them, and on the basis of the network management platform, the participants of the project can use the network to examine and approve audit documents and map files and so on, so as to realize the rapid sharing of information. It does well in improving the efficiency of engineering management [20].

(v) *Improvement.* Taking the advantage of BIM in the construction project management will help in the reduction of construction time of the construction projects greatly. Further, it will improve the speed of the building engineering, promote the intelligent development of the building equipment, and ensure the construction quality of the construction engineering. At the same time, the use of BIM can coordinate and adjust all kinds of engineering data, promote the improvement of management efficiency, save more human resources, material resources, etc., and is more beneficial for the society and building [21].

2.1. Data Analysis of Construction Engineering Management Project. In order to analyze the data in an effective way, there is a need to build a data management system platform.

When the number of managements is enlarged, various software functions of BIM technology have become more powerful, and more model-based systems have been investigated for the fusion of information of items [22]. This paper uses the combination of database, BIM technology, and network to share the virtual model and data and set up a data management platform based on BIM to realize the integration, management, analysis, and sharing of mass information in the construction phase of the project. Further, it provides a platform for high efficiency information communication and cooperative work for each participant. Before the system platform is set up, the following problems should be solved: (1) the integration and optimization of model data; (2) how to solve the problem of display and smooth operation of BIM model in web; (3) how to relate the engineering data and information to the 3D model; (4) how to implement the data for different participants in a unified management platform; (5) sharing and retrieval. Thus, establishing a system management platform reasonably according to the functional requirements is important. Through the in-depth study of the current BIM technology, Web3D, database management, data management, and other related technical fields, the functional framework of three major plates, such as data service layer, functional platform layer, and extensible application layer, is presented, as shown in Figure 1.

Realizing the optimization management items of the BIM database of construction engineering systems, on the basis of the abovementioned platform, it should build the relevant learners of BIM database, assuming that it is the construction project management BIM. This shows the quaternion (E_i, E_j, d, t) trust relationship among data and attributes $A = \{A_1, A_2, \ldots, A_m\}$ of management [23]. Express the BIM local database as the subsystem as follows:

$$\mathrm{Infor}(x, y) = \frac{x_i u_i}{\sum_{j=i}^{N}\left(2m_j/\sum_{k=j+1}^{N+1} L_k p_k - \sum_{k=j}^{N} E_k\right)} - 1, \quad i = 1, \ldots, N+1. \tag{1}$$

In the expression, i.e., $x_i \in R^n$, it is the state vector of the BIM database system for building engineering project management, and the input vector of the BIM database index control for construction engineering project management, $u_i \in R^m$. In general, for the BIM data association rule, metadata, and structural attenuation channels for original construction project management by integrating the initial query of BIM data relation $A = \{A_1, A_2, \ldots, A_m\}$ of construction engineering project management are calculated. Further, the index control input of BIM database subsystem of local construction project management in BIM database system of construction engineering project management is also calculated. In order to form a relative query result S and a relaxed query result and execute entity difference query on $\widetilde{Q}$, let $z^* = z \ggg 25$, and z^* and z are bit permutations. The mathematical model of the BIM database system can be expressed as follows:

$$\begin{gathered} K_i = key_i \boxplus W_i, \quad i = 0, 1, \ldots, 15, \\ p_k\left(S_k - S_{i-1}\right) + p_{k+1}\left(S_i - S_k\right) = p_i\left(S_i - S_{i-1}\right), \end{gathered} \tag{2}$$

where the value of "i" ranges in $i = 16, 17, \ldots, 63$. The 3D building model is established according to the related information and the BIM number is provided by many other ways. The schematic diagram of the relative correlation state system according to the library is shown in Figure 2.

2.2. Database Construction and Feature Reorganization. Construction of database system using B/S (Browser/Server) structure, users as IE, and shared connections to networks all over the world can realize the information. Most of the servers are implemented through the network connection between two terminals; and one can get instant data transmission and processing integration through it. Such system architecture is divided into 3 layers: the operation layer, application layer, and data service layer. The first layer is the user interface, for the end user group (including the owner, the design unit, the general contractor, the subcontractor, and the end-users) through the web browser. The user group is within the network license (special line, VPN, and even the whole WAN), through the HTTP network protocol, and through the identity, i.e., IP. The identification and corresponding operating authority wait after entering the system and related operation. The middle one is used for different applications which are interconnected into networks while the third one is the data service.

Among them, the data stream synchronization trigger is an important component of BIM. For the realization of the system in the database, the trigger is an application loaded in the database of all data table-space. Using the components, current application instructions issued by any operation (search, insert, delete, etc.) can be the synchronous trigger in database integration and user feedback to the corresponding operation. In a general information management system, if someone wants to use the data if the components of the system are not integrated, then the system cannot provide the integrated data, the database, or will be unable to provide each part of the project to integrate the data management function as shown in Figure 3.

The number of features in the BIM database is less than that of the original features, so the elements x_t in X are satisfied as

$$P\left(x_t | x_{t-1}, x_{t-2}, \ldots, x_1\right) = P\left(x_t | x_{t-1}, x_{t-2}, \ldots, x_{t-n}\right). \tag{3}$$

That is, x_t is only related to n elements of the relevant construction project. $x_t \in B$ is defined as the number of times of S passing through $\theta_{i_1, i_2, \ldots, i_{n+1}}(x)$, X, and equal states to i_1 in i_{n+1}. The feature set is set to $t = 0.5$. If the feature dimension is too low, the classification accuracy is the lowest and then the number of association rules should be carried out. According to the structural distribution reorganization, the binary vector is used to describe the feature to optimize

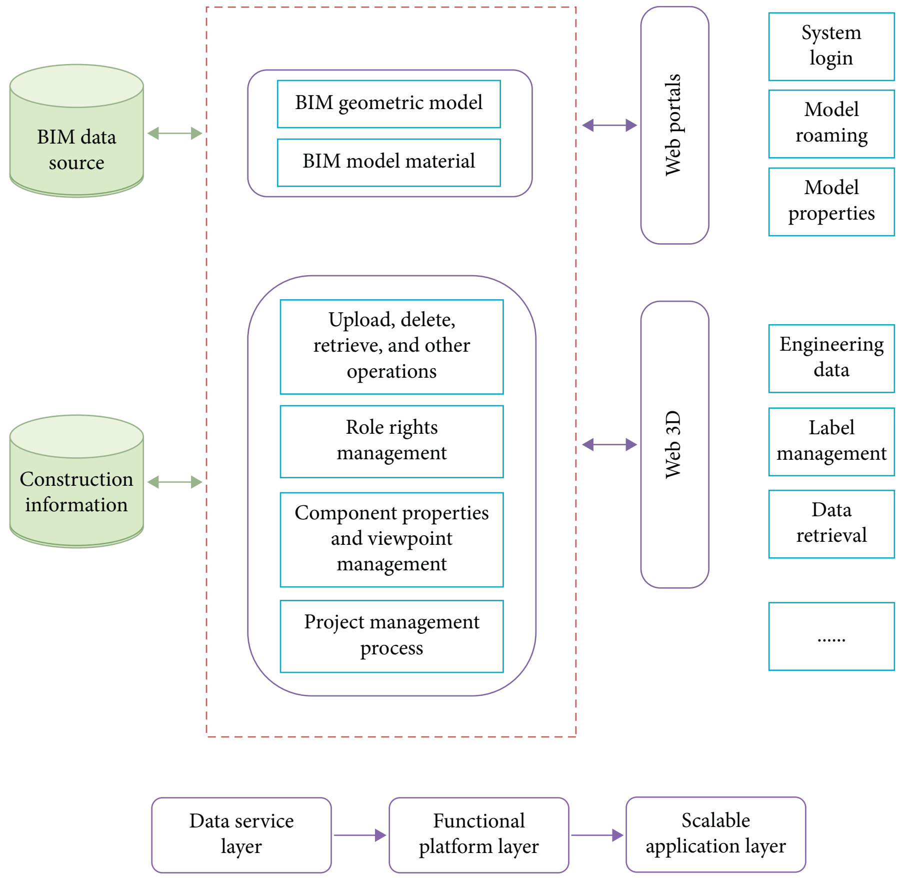

Figure 1: Data management system platform.

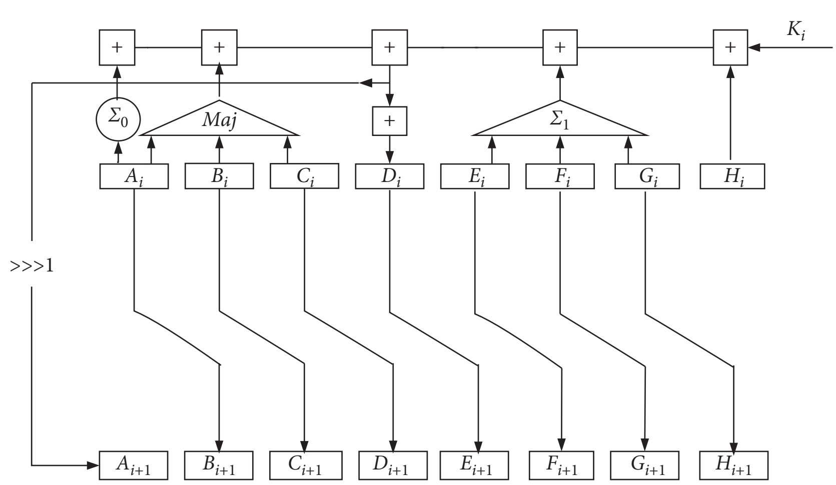

Figure 2: Schematic diagram of the relative associated state structure of the BIM database for construction project management.

the structure, $S = \{s_1, s_2, \ldots, s_n\}$, and the reconstruction process is obtained as shown in Figure 4.

3. BIM Technology Optimization of Engineering Project Management

3.1. Dynamic Data Analysis of Project Engineering Management. Associated with the knowledge-based data, in this paper, we build a 3D building model to improve the effectiveness of management. The whole model is expressed as follows:

$$Q_{\text{rev}}(\tau) = \frac{(1/N-\tau)\sum_{i=1}^{N-\tau}\left(x_i - x_{i+\tau}\right)^3}{\left[1/N - \tau\sum_{i=1}^{N-\tau}\left(x_i - x_{i+\tau}\right)^2\right]^{3/2}}, \tag{4}$$

where q_i construction items have n_i nearest feature $d_i = (d_{i1}, d_{i2}, \ldots, d_{in_i})$; there are

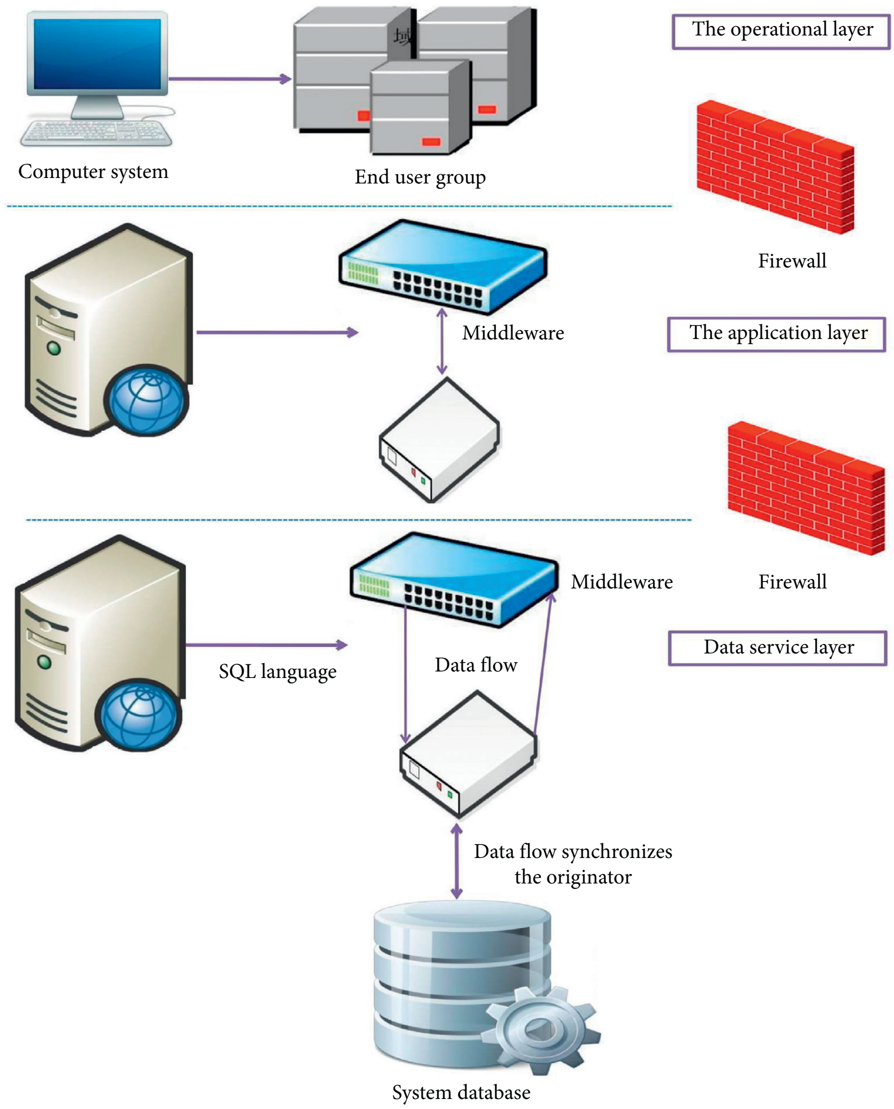

Figure 3: Database network architecture.

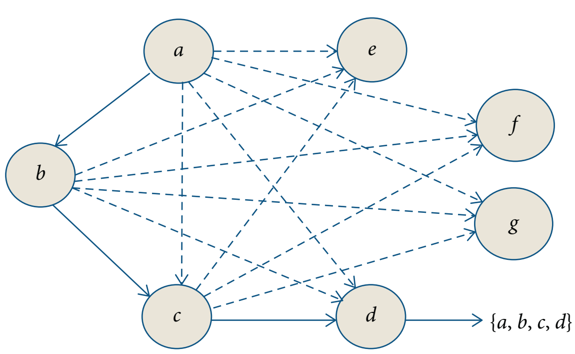

Figure 4: Data structure distribution reorganization process for construction projects.

$$W(q_i, d_{ij}) = \frac{g(q_i, d_{ij}) \times \log_2[f(d_{ij}) + 1]}{\sum_{j=1}^{n_i}\{g(q_i, d_{ij}) \times \log_2[f(d_{ij}) + 1]\}}. \tag{5}$$

Average M_i metrics are used for thresholds of the multilevel time attribute of BIM database, h-dimensional data matrix is reached, and the maximum value $C = [X_1, X_2, \ldots, X_n]'$ is obtained to realize the construction workers. Characteristic analysis of multilevel time attributes in process project management BIM database assuming the distribution scale $X(t)$ of the BIM database recommended by the multimodel for construction project management is to be standardized in the form

$$X'(t) = \frac{X(t)}{\|X(t)\|}, \tag{6}$$

where $\|X(t)\|$ represents the Euclid norm of $X(t)$ and maps the BIM data points near the origin to the upper half plane through adaptive threshold optimization. The multimodel recommendation relationship diagram is constructed, and the project is built by utilizing three-dimensional method. The analysis model of engineering management, the information of BIM data node of information construction project management is defined as (x_i, y_i), and the attribute weight of multilayer temporal attribute access channel is assigned as follows:

$$Hw(t) = \frac{\left|p_{i,j}(t) - \Delta p(t)\right|}{p_{i,j}(t)} \frac{p'\pi}{2} = \alpha' = \arctan\left(\frac{\tan\alpha}{M^2}\right). \quad (7)$$

The spectral estimation value of BIM data access for construction project management is expressed as follows:

$$(x, v)x = \frac{t}{S}, \quad v = f * S. \quad (8)$$

In order to realize the multimodel recommendation, the database will produce repeated access features after exchanging the BIM data, which is to input the BIM data. The row is patched, and then the BIM data for building project management that matches areas that are duplicated outside the area forms a new mapping in multiple source nodes and is given as follows:

$$x_n = [x(0), x(1), \ldots, x(N-1)]^T. \quad (9)$$

In the construction of BIM data temporal distribution in construction engineering project management, the temporal attributes of BIM database in construction project management are assumed which defines the distance between two points, i.e., n_1 and n_2, as a normal distribution and defines consistency index, $N = \Delta x^2$, in interval $[-\Delta x/2, \Delta x/2]$ and is completely consistent.

3.2. Database Optimization Access Technology for Construction Project Management. This section represents the use of BIM technology and database optimization techniques to process the management data. The multimodel recommendation algorithm is used to reconstruct the multilevel time attributes of the BIM database of construction project management. The binary vector description feature is used to optimize the structure of the model, and the BIM database is set up for instruction scheduling. The geometric features of the BIM data of multidimension state construction project management can be obtained from the N samples $x_1, x_2, \ldots, x_N$, and the differential cumulative function features of the BIM database can be obtained:

$$y[n] = \sum_{i=0}^{M} a_i x[n-i] + \sum_{i=1}^{M} b_i y[n-i], \quad (10)$$

where $a_0, a_1, \ldots, a_M$ denotes differential cumulant vector and $a_i(i = 0, 1, \ldots, M)$ and $b_i(i = 1, \ldots, M)$ are characteristic coefficients of differential cumulative function. In BIM data fusion center of the model is obtained as follows:

$$\min_{A,S} \frac{1}{2\sigma^2}\|AS - X\|^2 + \sum_{i,t}\left|s_i(t)\right|. \quad (11)$$

In the BIM database access system of construction engineering project management, the fuzzy clustering algorithm is used for data clustering analysis, and the multilayer temporal attributes of BIM database are obtained as follows:

$$X_p(u) = g'_\alpha(u)\exp\left[-j\pi t^2 \tan\left(\frac{\alpha}{2}\right)\right]. \quad (12)$$

Based on the k-order origin moment estimation of the depth of the BIM data of multilayer temporal attribute, the multilayer temporal attribute of the BIM database of the above construction project management satisfies the multimodel recommendation feature, which is expressed as

$$g'_\alpha(u) = A_\alpha \int_{-\infty}^{+\infty} \exp\left[j\pi(u-t)^2 \csc\alpha\right] g(t)\mathrm{d}t. \quad (13)$$

4. Simulation Results and Experimental Analysis

This section of the paper represents the experiments performed and the simulation results carried out via those experiments. Multiple simulation experiments were conducted on the BIM data management and engineering project organization management and adopted the BIM data combination method for CWT200G construction project management. We established a project management BIM database structure model for the network text information construction project in the real environment. The random sampling method has obtained more than 100,000 BIM data for construction project management and conducted experiments. Multiple experiments were performed using various parameter settings. Among the experiments and simulation results the top two are discussed here. There are some important parameters that need to be set with proper values such as data sampling iteration step, loop iteration count, data size, correlation coefficient, support threshold value, and minimum support threshold value. All the experiments have been performed on a laptop computer (Intel Core-i7, 7th generation, having a processor of 2.7 GHz, RAM of 16 GB, and the operating system on which it operated was Windows 10).

In experiment one of the construction project management, the BIM data sampling iteration step was set to 0.003, the loop iteration count is 100, the data size is 200 T bits, and the correlation coefficient is 0.25. In the construction project management, the minimum association rule function of the BIM database data structure is obtained. The support threshold is set to 2.0% and the minimum support threshold of the database is set to 30.0%. According to the above simulation environment and parameter settings of the project management model, a 3D rendering method is used to construct a dynamic data analysis model for project engineering management.

On the basis of 3D dynamic management, the performance comparison of data optimization management is obtained as shown in Figure 5.

From the analysis of Figure 5, it is obvious that when the number of data instances increases, the BIM data matching efficiency of the project management of system 1 method is increasing gradually, and it reaches the maximum value of 410 kbits/s. The BIM data matching efficiency of the engineering project management of system 2 methods is also increasing gradually, and the data matching efficiency

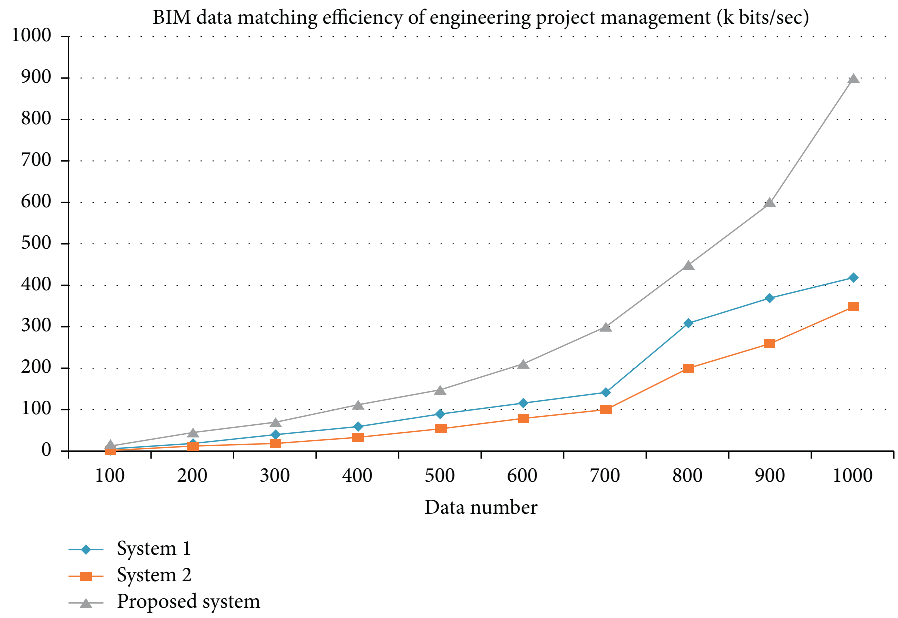

Figure 5: Performance comparison analysis of experiment one.

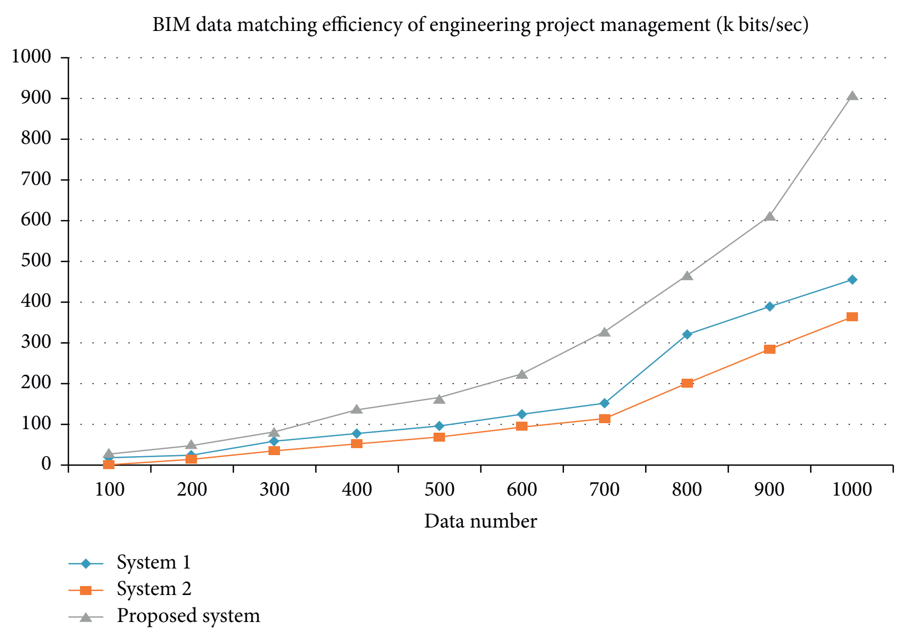

Figure 6: Performance comparison analysis of experiment two.

reached to the maximum value of 360 kbits/s, which is the lowest of the three utilized methods. The method proposed in this paper attained the highest spot in this competition. The BIM data matching efficiency of the project management method proposed in this study increased gradually as the size of data increased. When the number of data reached 1000, it reached 900 kbits/s, which was the highest of the three methods used in this study. Therefore, the model is applied to project management, and the retrieval ability of relevant information data is good, and the database access efficiency is high.

In the second selected experiment of the construction project management, the BIM data sampling iteration step was set to 0.005, the loop iteration count is set to 110, the data size selected is 200 T bits (same as the experiment one), and the correlation coefficient is 0.30. In the construction project management, the minimum association rule function of the BIM database data structure is obtained. The support threshold is set to 2.0% and the minimum support threshold of the database is set to 25.0%. According to the above simulation environment and parameter settings of the project management model, another 3D rendering method is used to construct a dynamic data analysis model for project engineering management.

Figure 6 shows a comparison of the performance of data optimization management based on the 3D dynamic management of the three utilized methods in this study.

Figure 6 illustrates that the BIM data matching efficiency is directly proportional to the increase of data instances; i.e., when the number of data instances increases, the BIM data matching efficiency is increasing for all the methods used in this paper. The BIM data matching efficiency of the project management of system 1 method is increasing gradually, and it reaches the maximum value of 460 kbits/s when the data number reached 1000. The BIM data matching efficiency of the engineering project management of system 2 methods is also increasing gradually, and the data matching efficiency reached the maximum value of 385 kbits/s when the data number reached 1000. The method proposed in this paper outperformed the two utilized methods and attained the highest spot in terms of performance. The BIM data matching efficiency of the project management method proposed in this study increased gradually as the size of data increased. When the number of data reached 1000, it reached 910 kbits/s, which was the highest of the three methods used in this study. The lowest performance was observed for system 2 in both of the experiments while system 1 attained the second spot in the performance competition. Keeping the performance and data matching efficiency of the method proposed in this study, the model is highly efficient to be applied to the project management, as the retrieval ability of relevant information of the data is impressive, and the database access efficiency is very high. In short, this model will be highly valuable and helpful for the managers and team of the construction engineering project management to carry out their projects in a smooth and efficient way.

5. Conclusions

The construction business is continually evolving; building projects are becoming larger and more complicated, and construction periods are becoming longer, all of which raise the bar for project management. Maintaining and decreasing the cost of engineering projects are significantly important to improve the economic benefits of engineering projects. In this study, a 3D architectural model is established by using the fuzzy balanced scheduling in order to decrease the complexity of scheduling and clustering analysis of corresponding information data for the construction project. The model uses various parameters and is used throughout the life cycle of the construction engineering project management. The proposed system is based on the BIM technology that coordinates different positions and departments and accurately displays resource consumption. In addition, the proposed system uses a 3D rendering technique along with the optimized database access technology to build a dynamic model to capture the basic project management data and to deliver a project within time and budget. Further, different experiments have been performed for measuring and tracking the performance of the proposed system. Performance of the proposed system has been compared with two other state-of-the-art approaches. The experimental result shows that the proposed system performed significantly better as compared to the other systems. The proposed system is anticipated to be highly helpful and valuable for the construction engineering management projects. Future work of this study includes using more data, parameters, and scheduling algorithms that really reduce the project management time and proposing more optimization algorithms in order to deliver a project within budget.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that he has no conflicts of interest.

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Review Article

Selection of Crowd in Crowdsourcing for Smart Intelligent Applications: A Systematic Mapping Study

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Crowdsourcing is a task-solving model in which human crowd is hired to solve a particular task. During the crowdsourcing process, the crowd selection is performed in order to select appropriate crowd workers for a specific task; without appropriate selection of crowd workers, the process of crowdsourcing is aimless. The main goal of this paper was to identify the features of crowd in crowdsourcing activity, reasons behind crowd participation in the activity of crowdsourcing, and the existing techniques that were utilized for crowd selection in crowdsourcing. Search strings with corresponding keywords were used to capture relevant studies related to crowdsourcing, and crowd selection was classified under conference papers, journal articles, proceedings, and book chapters. 81 relevant studies are selected from 7 digital data repositories using a search strategy. In crowdsourcing practices, crowd selection was considerably addressed. Nonetheless, it has been noticed that the selection is based only on a single crowd worker attribute such as confidence, past success, efficiency, and experience. For the efficiency and effectiveness of the crowdsourcing operation, crowd selection on multicriteria features is essential.

1. Introduction

Crowdsourcing is a task-solving model in which human crowd is employed for solving complex tasks [1]. It is an online activity that is used for gathering the collective knowledge, skills of people in order to complete an ordinary task [2]. Using crowdsourcing, an organization outsources different types of tasks to a huge crowd using an open call. The term crowdsourcing was first coined by Jeff Howe; in the magazine, *Wired*, he defined it as "the act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call." Crowdsourcing is a popular approach that is used for performing various activities. The process of crowdsourcing consists of different entities and their interactions such as requester/crowdsourcer/clients who plan, organize, and manage crowdsourcing projects and are capable of submitting the task request, managing the crowd which consists of an online workforce that participates in crowdsourcing tasks or projects, and providing a platform that provides a communication link between the crowd and the requester, i.e., to cope with the task and the crowd [3–7]. Different tasks are performed with the help of crowdsourcing, such as spell checking, creating contents, simple coding, machine learning, distributed solution of a problem like in the development of software and its testing. The tasks are posted on a platform and the crowd participates for performing various types of tasks [6, 8–10]. In crowdsourcing, participants with various backgrounds, levels of qualification, different expertise in various areas, and having various skills and experience work together to perform a specific task or to solve diverse problems [11–14]. Organizations use crowdsourcing applications as the participation of a huge crowd will enable large challenging tasks to be performed or solved in parallel by the crowd. Crowdsourcing is as an effective means for finding a solution toward a corporate problem [15–17]. Crowdsourcing allows organizations (clients) to recruit global, cheap, and skilled work force through online platforms [18, 19].

Nowadays, with the help of the Internet, companies are capable of hiring a large group of people with a little effort, as the Internet provides a communication link through which people and organizations can collaborate with each other using different devices such as mobile phones, tablets, iPad, and wearable devices [1, 9, 20–23], and platforms like Amazon Mechanical Turk (AMT) are used by organizations to hire a huge crowd from the global community for accomplishing different types of tasks [24]. In crowdsourcing, an organization can obtain high-quality solutions in less time with a little investment, as it allows a lot of people to complete various tasks with negligible employment and management expenses [25, 26]. As crowdsourcing is an Internet-enabled activity, the online platforms give rise to certain challenges such as the issue of how to announce tasks or jobs, how to select an appropriate platform for submitting task requests, and how to recruit competent people [27]. Recruitment of workers becomes a challenging phase with the increase in the popularity of crowdsourcing. In a large crowd of humans, there might be an untrustworthy participant that often makes mistakes in solving different types of tasks. The identification of the right worker makes the crowdsourcing activity successful [14, 28, 29] for the enhancement of developmental process units, if right skill crowd is hired [30].

In a crowdsourcing task, workers' behaviors and their attitudes are significant features for engaging workers. The crowd must perform the task in the best possible way as the engagement of the crowd depends highly on valuable outcomes. The engagement process will make recruiters able to engage the right worker from a large pool of the crowd. Worker engagement might be influenced by work and worker characteristics. Work characteristic includes task characteristics in which the engagement of the crowd depends highly on the autonomy of task, and it will increase the level of participation with the flexibility and mobility in tasks. The task dissimilarity may influence the participation of workers as irresponsible workers might violate rules of a task. The performance of crowd workers will be increased with the feedback related to their task and they will carefully perform various tasks. Crowd worker's visibility is the second worker characteristic that has a positive impact on the engagement of the crowd as participants will be visible to organizations. By an increase in the visibility level, workers might be identified among a large crowd pool. The third characteristic of work is Work Setting, on engaging workers for performing a task the worker setting and environmental characteristics play an important role. Organizations have provided a number of options for workers to participate. Crowds can participate virtually from homes, shops, and even from other places of employment. With the increase in potential work setting, the availability, flexibility, and independence of workers is increased, and it will probably increase the performance and satisfaction of workers. The fourth work characteristic is worker recognition, which has practical influence on participant engagement. There are certain factors that drive worker engagement in a job. The unknown nature of crowd work brings some of the challenges that are concerned with the best identification and recognition of crowd workers and how to reward high performers. Personal recognition might be affected by anonymity in crowd settings. Recognition and rewarding participants has shown that the achievements directly impact attitudes and behaviors of workers. Recognition may increase worker engagement by revealing to the crowd that they are valuable assets of the organization. Individuals enroll for complex tasks not because of reward but they think that they will be valued by the organization. By receiving recognition from the organization, individual involvement will be improved and one will put in his or her best efforts and concentration in performing tasks.

Crowd worker characteristics are also responsible for worker engagement. It includes Worker Expectations, Extrinsic Motivation, Satisfying Motivation, and Meaningfulness. Worker expectations represent the expectation of crowd workers in an activity from client organizations for their participation in performing a task. The workers who register themselves for performing tasks have certain expectations regarding requirement of the task, period of completion, complexity, and cognitive load that is mandatory for completing the task. When these expectations are violated, they impact comfort, motivation, and satisfaction of workers. Before participation, workers are provided the relevant information about the task such as requirement of the task, the period of completion, and the exact remuneration to participants. With this, the crowd can participate and select the tasks in which they are interested and which matches their skills level. A worker will participate in a task if the task is simple, only less effort is required for thinking, and can be completed in less time. If workers are not provided with task information, they might participate in complex tasks, might become frustrated with the increase in mental effort, and will waste much time. This will affect the behavior and attitudes of workers, thereby lowering the engagement of workers. Crowd workers may be engaged due to the extrinsic motivation factor in which the crowd participates in activities and they are provided with money or reward. There is a liner relation between crowd engagement and extrinsic motivation. Another characteristic is Satisfying Motivation in which the crowd workers expend their cognition, physical, and emotional energies for performing various tasks. Individuals contribute with a goal for achieving the best probable outcomes (example, task performance level). For attaining this, participants use their efforts and concentrate on tasks, and perform well beyond the requirements of satisfiers. A crowd worker depends on resources for achieving high performance level and this will increase the level of engagement of workers. Contrary to satisfying motivation, participants consume their energy, which is required to generate a "good enough" result, and, as a result, decrease the complete engagement of participants in a task. Meaningfulness is another crowd worker characteristic for engaging a crowd; it reflects the degree to which the participants analyze that their contribution is important. Their work is appreciated, valued by clients. This can impact working outcomes such as performance, motivation, and satisfaction. By observing that the tasks performed by workers are valued and accepted, i.e., their efforts are not countless, their interest in engagement will be increased and they will spend more energy in the accomplishment of tasks [31].

Analyzing crowdsourcing and its importance in today's business world, a systematic literature review was carried out for the last ten years, i.e., 2010–2020. The proposed research study is composed of three-fold contributions that are enumerated as follows:

(i) To identify the significant features of the crowd

(ii) To pinpoint the reasons behind the crowd for active participation in crowdsourcing activities

(iii) To explore various existing methods utilized for crowd selection in crowdsourcing

The presented systematic literature review (SLR) mainly focuses on crowd selection that will be used by various organizations to capture the appropriate crowd from a global community to perform various tasks.

The paper is structured in a linear fashion and is categorized into 9 sections. Section 2 briefly describes and discusses the overall research process carried out for this review. Section 3 explains the validation and threats for this review. Section 4 presents results and discussions of analyzed papers. Section 5 presents the research findings of the review. Section 6 briefly discusses the review topic. Section 7 concludes the review. Section 8 presents the limitation of the proposed review. Section 9 presents future research suggestions.

2. Research Methodology

With the interest to analyze the feature, motives of the crowd, and strategies used for the selection of a crowd in a crowdsourcing activity, a systematic literature review was carried out. SLR is a systematic practice for identifying and analyzing related studies as a regard to a specific interest area [32]. For ensuring validity and the value of SLR, a number of standards and protocols are applied by researchers. We adopted the protocol suggested by [33] in carrying out this research. The review protocol and its stages are represented in Figure 1. The review protocol comprised seven stages, namely, analysis of research topic, extraction of research questions, designing a search strategy, extraction of results from data, scrutiny, criteria for quality assessment, and synthesis of data. Research questions are extracted from various studies in the second stage; in the third stage, the searching strategies are designed in accordance with research questions that consist of search term identification and selection of literature resources; collection of extracted data takes place in the fourth stage of the protocol; the fifth stage is concerned with scrutinizing, i.e., refinement of extracted data; scrutinized studies are then evaluated based on a criteria of quality assessment in the six stage. In stage seven, selections of final prospective studies for analysis are carried out.

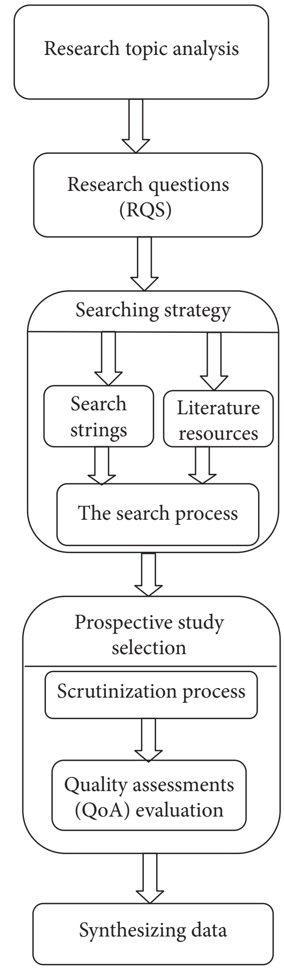

Figure 1: Stages of review protocol.

The following sections show the details of the research method.

2.1. Research Topic Analysis. Research papers from various digital data repositories were thoroughly reviewed to know the crowdsourcing concept, to discover the issue related to the field, and to find out what researchers have done so far to solve many problems over time.

2.2. Research Question. For getting a better perspective on crowdsourcing conception and to identify areas for researchers, a thorough assessment was carried out on the topic of crowdsourcing. Relevant papers, conference proceedings, book chapters, and journals were studied at the initial stage that clearly defined crowdsourcing activity. Our preliminary study identified that crowd selection is a problem-solving technique that is utilized by many organizations for the accomplishment of various tasks by harnessing the collective energy of humans. In order to carry out the research, the proposed study focuses on addressing some research questions given in Table 1 that are extracted based on the assessment of various articles/papers for the purpose of making this review an effective one.

2.3. Searching Strategy. Search terms, literature resources, and search processes make up the search strategy. The descriptions of each are discussed in subsequent steps.

2.3.1. Search String. For creating search terms, the following steps are carried out:

(i) From formulated research questions, major terms were derived
(ii) Synonyms are identified for main terms
(iii) Keywords were identified from relevant books or papers
(iv) Boolean OR is used to link synonyms
(v) Main terms are linked with Boolean AND

The strings that are formed as a result are presented as follows:

(i) (Multicriteria OR crowd OR crowd selection OR worker selection) AND (crowdsourcing) AND (software OR software engineering)
(ii) ("Multicriteria" OR "crowd selection" OR "worker selection") AND (crowdsourcing) AND (software engineering)

2.3.2. Literature Resources. For synchronization, a thorough assessment of the proposed study was carried out on seven digital libraries to extract data from various scholars' works on the topic of crowdsourcing. These digital libraries include: ScienceDirect, IEEE Xplore, ACM Digital Library, Springer, Taylor & Francis, Wiley, and Hindawi. For carrying out this research title, abstracts, index terms, contents of conference proceedings, published research papers, journal articles, book chapters, and conference papers were analyzed.

2.3.3. The Search Process. For a comprehensive search, a systematic literature review of relevant sources is significant to be carried out. Yet, the search process that is utilized in the proposed study consists of some stages that are mentioned below. These steps are also represented in Figure 2:

(i) Stage 1: seven digital libraries are thoroughly searched to extract papers related to the proposed research. The search result has been assembled to be a collection of prospective papers.
(ii) Stage 2: on the basis of titles, papers were filtered from total papers.
(iii) Stage 3: relevant papers were extracted by applying quality assessment criteria.

2.4. Prospective Study Selection. The first stage of searching retrieved 2098 metadata studies (abstract, title, contents) from seven digital databases. After this stage, the titles of perspective studies were used for extracting relevant research work. This process is mandatory for the exclusion of irrelevant and duplicate research studies. After applying title base filtering, 146 related studies were identified. Finally, we applied quality assessment criteria (QoA) on the filtered papers, i.e., each paper was studied and assessed in detail to check whether these studies answer the questions that were formulated. At the end of this process, 81 relevant studies capable of answering the questions were selected.

2.4.1. Scrutinization Process. Scrutiny was necessary to extract the relevant work as we have obtained 2098 prospective studies in the initial search process. At first, title-wise paper selection was used to filter relevant papers. Next, the relevant studies are analyzed on the basis of paper contents. Hence, all articles that were unable to address our research question and do not reveal the discussion topic were excluded. Studies that are published in conferences, proceedings, journal publications, and written only in English were included in the relevant studies. Duplicate research studies were also eliminated in this process. A systematic literature review was carried out for a period of ten years, i.e., 2010–2020, in order to select recent studies on the topic. Our initial search process on seven digital databases was conducted between January 24, 2020 and January 29, 2020. The criteria adopted for the process of scrutiny is presented in Table 2.

Figure 3 shows the type of papers along with the year of publication.

Table 3 shows the library-wise search based on title and contents.

Figure 4 shows the reference of paper, types of paper with the year of publication.

2.5. Quality Assessment (QoA) of the Selected Papers. The quality of assessment was obtained for selected studies by scoring or evaluating these studies in order to check whether these studies are capable of answering formulated research questions or not. Such questions are dealt with in Table 4. There are only 2 answers (options) to each question, i.e., "yes" = 1 and "No" = 0. The quality score of each study is calculated as the sum of answering the formulated questions. The reliability of the proposed study was obtained by considering studies that are relevant and whose quality score is two or three, i.e., papers that are capable of answering at least two research questions. Based on quality scoring, 65 studies were excluded and 81 papers were selected as they were capable of answering at least two formulated questions. The quality scores of selected studies are shown in Table 5 and the graphical representation is represented in Figure 5.

Table 1: Representation of the research question.

#	Research questions	Aims
1	What are the significant features of the crowd for effective crowdsourcing?	In the crowdsourcing environment, the participating crowd has some features that are significant for assigning a task. We will analyze many of these features to make crowdsourcing activity efficient and effective.
2	What are the reasons behind the crowd to actively participate in crowdsourcing?	Nobody does anything free; everyone wants something in return. We have to point out the reason as to why the crowd participates in crowdsourcing
3	What are the existing techniques used for crowd selection in crowdsourcing?	Various techniques were used in past for crowd selection as without selecting the appropriate worker, the crowdsourcing activity is aimless. Existing techniques will be discussed briefly.

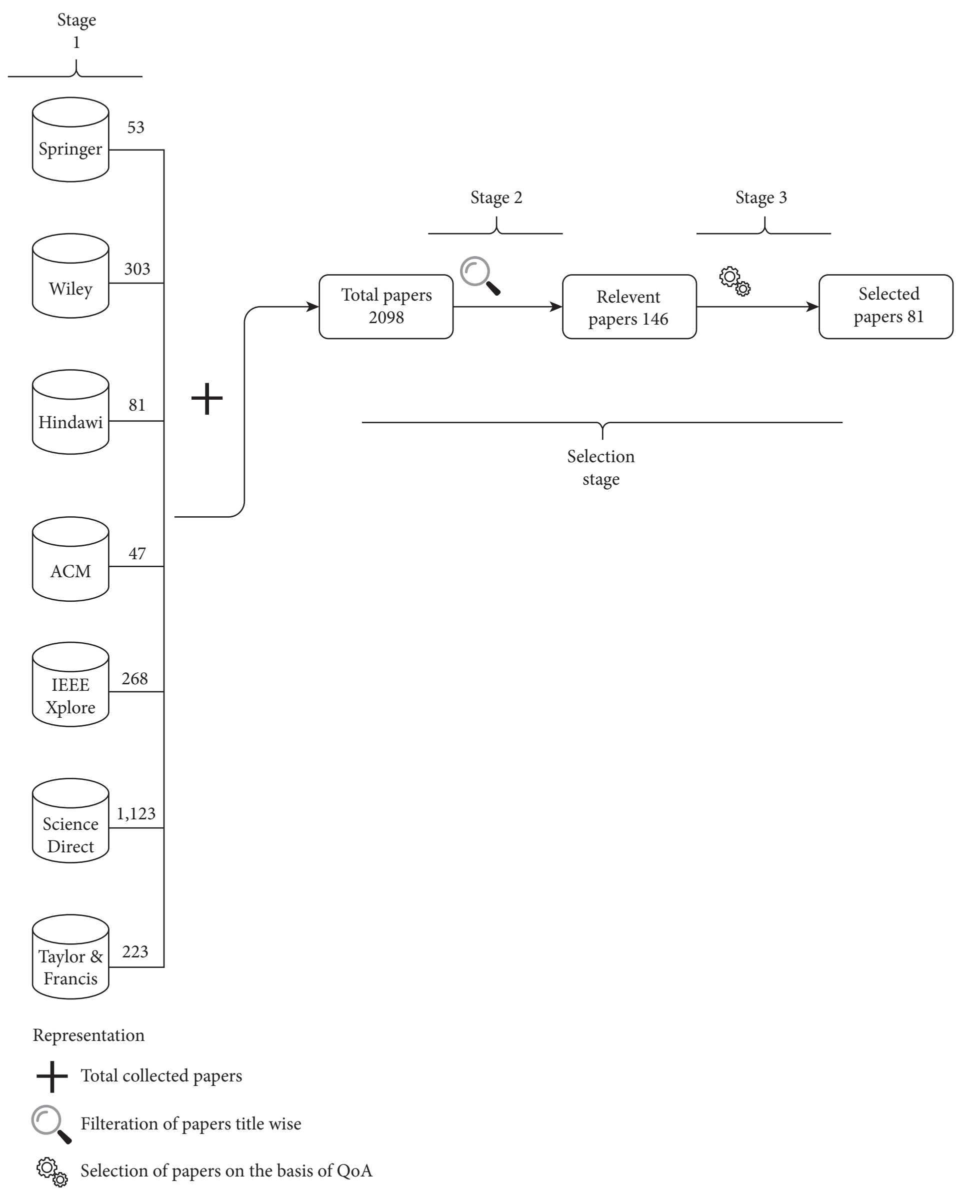

Figure 2: Representation of different stages of our search process.

Table 2: Criteria for inclusion/exclusion.

Inclusion Criteria	Exclusion Criteria
Articles that are published in English language	Articles that are published in other languages
Papers that focus on crowdsourcing	Papers that do not discuss the research topic
Papers that are published between 2010 and 2020	Papers that are published before the year 2010.
Papers that are capable of answering minimal two formulated questions	Papers that are incapable of answering two questions

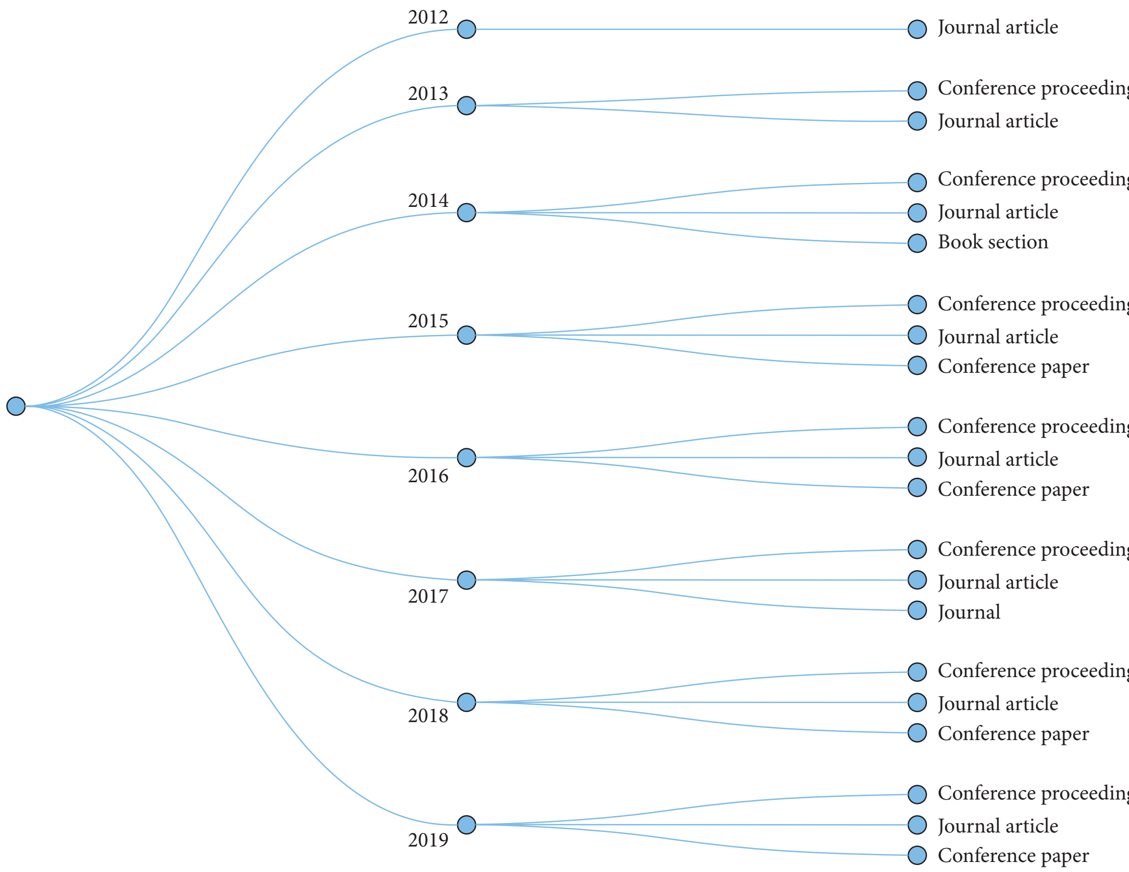

Figure 3: Type of papers with the year of publication.

Table 3: Library-wise search based on title and contents.

Libraries	Title-wise selection	Content-wise selection
Hindawi	3	2
Wiley	3	3
ACM digital library	9	6
Springer	10	6
Taylor and Francis	14	8
IEEE	43	23
Science direct	57	33
Total	7	81

2.6. Synthesizing Data. The significance of this step is to synthesize and summarize the proofs in order to answer formulated questions. Eighty-one relevant studies have been synthesized using thematic analysis, which is a powerful technique used to rigorously generate themes and patterns for data [84]. A theme extract is something significant about the RQ data, and it can be derived inductively or deductively from the data based on themes derived in previous studies. The process will help in synchronization of the relevant study in order to intensify clarity. This will also assist in identification of specific answers to formulated questions. A summary of data synthesis for the research question is explained below. The data associated with all RQs is represented in a table form and it is also discussed in detail. In RQ1, the features of the crowd are extracted from selected studies. RQ2 explains in detail the reasons for crowd participation in an activity. RQ3 focuses on various techniques used for crowd selection.

3. Results and Discussion

This segment summarizes the findings of the study. First, we present an overview of selected articles. Next, we present in separate subsections a description of the results of the review process, in accordance with the questions formulated.

3.1. Overview of Selected Papers. For the proposed study, 81 Research studies are selected on the basis of QoA criteria. Among these studies, 55 papers were published in journal articles, 1 paper in book section, 20 are extracted from conference proceedings, and 5 studies were retrieved from conference papers. The total number of selected papers and their percentages are presented in Figure 6; the selected papers based on publication year are shown in Figure 7.

3.2. Significant Features of Crowd in Crowdsourcing (RQ1). Organizations are interested in leveraging and gaining the knowledge of people. Superior techniques are applied for collecting this knowledge from external experts for enhancing the performance of products. Managers of an organization who are interested in solving challenges must select specialized professionals or subject experts from the external world who have the knowledge for solving a new

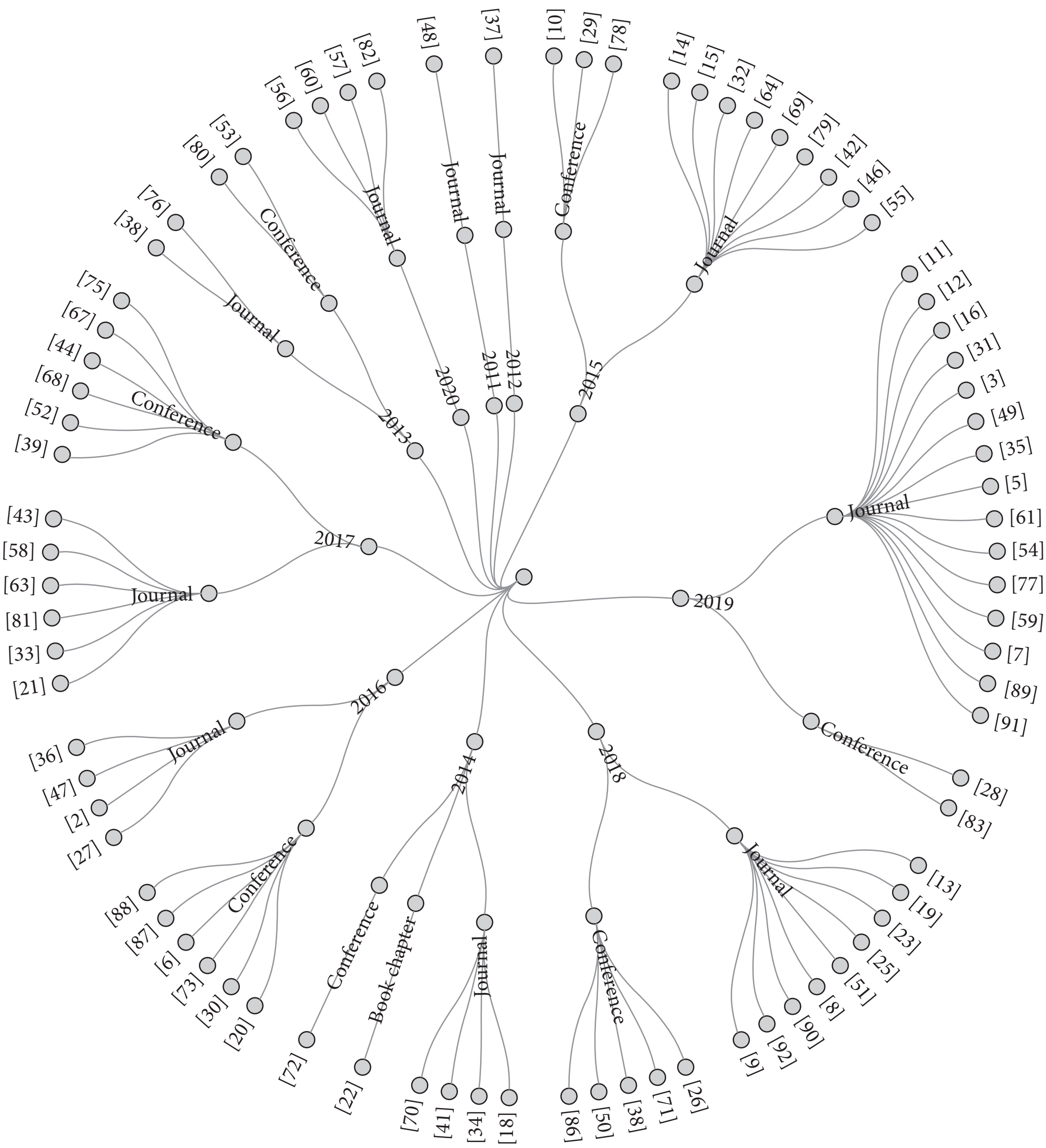

Figure 4: Reference, year, and type of paper.

Table 4: Representation of quality assessment criteria.

S. no.	Questions
1	Are the studies representing the features of the crowd?
2	Do the papers answer as to why the crowd participates in an activity?
3	Does the research point out the techniques for crowd selection?

organizational challenge. These specialized persons represent a solid approach to increase the absorptive capacity or the company's capability to identify, assimilate, and exploit external knowledge. Various approaches are used by specialized professionals for increasing the storage capacity, or they may use the potential of the company for identifying, selecting, assimilating, and utilizing the knowledge of experts [71]. In crowdsourcing, the entire project or a part of it is outsourced to a large pool [39], of distributive and cost effective's labors [72]. Crowd workers possess some characteristics, i.e., they can be identified with certain rules that direct their behaviors, they do not depend on others, they control their actions, and they may be flexible [34, 81] in changing their behavior with the changing environment [34]. Crowd workers may be newcomers (novices) [12, 20, 41, 47]; anonymous participants [3, 6, 7, 11, 19, 73, 83]; inexperienced [11], fraudulent [1], incompetent [21] workers; heterogeneous workers [38, 52, 56, 64] in working styles; unknown workers [73]; transient solvers (it greatly influences the quality of a task) [83]; undefined workers [3]; nonprofessionals [49, 56, 83]; nonexperts [49, 68]; untrained participants [3, 35]; untrustworthy workers only interested

Table 5: Quality score results of selected studies.

Cite no.	Title	Q1	Q2	Q3	Score
[34]	A hybrid simulation model for crowdsourced software development	1	0	1	2
[35]	A vision of crowd development	1	1	0	2
[36]	Affinity-aware online selection mechanisms in mobile crowdsourcing sensing	1	1	1	3
[37]	An exploratory study on perception of Indian crowd toward crowdsourcing software development	1	1	0	2
[16]	Analyzing crowd labor and designing incentives for humans in the loop	1	1	0	2
[38]	Barriers faced by newcomers to software crowdsourcing projects	1	1	0	2
[39]	Competence, collaboration, and time management: Barriers and recommendations for crowd workers	1	1	1	3
[19]	Competition-based crowdsourcing software development: A multi-method study from a customer perspective	1	1	0	2
[15]	Crowd development	1	1	0	2
[40]	CrowdService: Serving the individuals through mobile crowdsourcing and service composition	0	1	1	2
[41]	Crowdsourced software development: Exploring the motivational and inhibiting factors of the South African crowd	1	1	0	2
[42]	Efficient worker selection through history-based learning in crowdsourcing	1	1	1	3
[24]	Estimating software task effort in crowds	1	0	1	2
[43]	Guiding the crowds for android testing	1	1	0	2
[44]	Leveraging crowdsourcing for team elasticity: An empirical evaluation at TopCoder	1	0	1	2
[45]	Leveraging the power of the crowd for software testing	0	1	1	2
[22]	Supporting coordination in crowdsourced software testing services	1	1	1	3
[13]	Task allocation for crowdsourcing using AI planning	1	1	1	3
[4]	Toward microtask crowdsourcing software design work	0	1	1	2
[28]	Toward adopting alternative workforce for software engineering	1	0	1	2
[17]	Virtual team performance in crowdsourcing contest: A social network perspective	1	1	0	2
[46]	Who should be selected to perform a task in crowdsourced testing?	1	0	1	2
[47]	Worker ranking determination in crowdsourcing platforms using aggregation functions	1	1	1	3
[48]	A fuzzy expert system to trust-based access control in crowdsourcing environments	1	1	1	3
[49]	A survey of the use of crowdsourcing in software engineering	1	1	1	3
[3]	A systematic literature review on crowdsourcing in software engineering	1	1	1	3
[50]	An incentive mechanism with privacy protection in mobile crowdsourcing systems	1	1	1	3
[51]	A system for scalable and reliable technical-skill testing in online labor markets	1	0	1	2
[52]	Auction-based crowdsourcing supporting skill management	1	1	1	3
[18]	Best of both worlds: Mitigating imbalance of crowd worker strategic choices without a budget	1	1	0	2
[31]	Catering to the crowd: An HRM perspective on crowd worker engagement	0	1	1	2
[53]	CloudTeams: Bridging the gap between developers and customers during software development processes	1	1	1	3
[54]	Competition matters! self-efficacy, effort, and performance in crowdsourcing teams	1	1	0	2
[12]	Cooperation or competition—When do people contribute more? A field experiment on gamification of crowdsourcing	1	1	0	2
[11]	Crowdsourcing: A taxonomy and systematic mapping study	1	1	0	2
[55]	Crowdsourcing contests	1	1	0	2
[21]	Crowdsourcing not all sourced by the crowd: An observation on the behavior of Wikipedia participants	1	1	0	2
[56]	Efficient crowdsourcing of unknown experts using bounded multiarmed bandits	1	1	1	3
[57]	Hybrid crowd-based decision support in business processes	1	1	1	3
[58]	Improving accuracy and lowering cost in crowdsourcing through an unsupervised expertise estimation approach	1	0	1	2
[59]	Incentivizing social media users for mobile crowdsourcing	1	1	1	3
[60]	Information technology (IT)-enabled crowdsourcing: A conceptual framework	1	1	1	3
[61]	Inspiring crowdsourcing communities to create novel solutions: Competition design and the mediating role of trust	1	1	0	2
[62]	Mobile crowd sensing—Taxonomy, applications, challenges, and solutions	0	1	1	2
[63]	Modeling cognitive bias in crowdsourcing systems	1	1	0	2
[64]	Open or proprietary? Choosing the right crowdsourcing platform for innovation	1	1	0	2
[23]	Privacy-preserving QoI-aware participant coordination for mobile crowdsourcing	0	1	1	2
[2]	Real-time crowdsourcing with payment of idle workers in the retainer model	1	1	0	2
[65]	SenseChain: A blockchain-based crowdsensing framework for multiple requesters and multiple workers	0	1	1	2
[14]	The wisdom of crowds: The potential of online communities as a tool for data analysis	1	1	0	2
[30]	Toward collaborative software engineering leveraging the crowd	1	1	0	2
[8]	Trait motivations of crowdsourcing and task choice: A distal-proximal perspective	1	1	0	2
[9]	Trust-based privacy-aware participant selection in social participatory sensing	0	1	1	2

Table 5: Continued.

Cite no.	Title	Q1	Q2	Q3	Score
[6]	Understanding crowdsourcing projects: A systematic review of tendencies, workflow, and quality management	1	1	1	3
[66]	Weaving risk identification into crowdsourcing lifecycle	0	1	1	2
[67]	Winners, losers, and deniers: Self-selection in crowd innovation contests and the roles of motivation, creativity, and skills	1	1	0	2
[29]	A context-aware approach for trustworthy worker selection in a social crowd	1	1	1	3
[68]	A survey of task-oriented crowdsourcing	1	1	1	3
[27]	An investigation of factors affecting the visits of online crowdsourcing and labor platforms	1	1	0	2
[69]	Improving reliability of crowdsourced results by detecting crowd workers with multiple identities	1	1	0	2
[10]	Volunteer selection based on crowdsourcing approach	1	1	1	3
[70]	Why incorporating a platform-intermediary can increase crowdsourcees' engagement	1	1	0	2
[71]	A conceptual framework for increasing innovation through improved selection of specialized professionals	1	1	1	3
[72]	Facilitating collocated crowdsourcing on situated displays	1	1	0	2
[73]	Framework and literature analysis for crowdsourcing's answer aggregation	1	1	0	2
[74]	Practical POMDP-based test mechanism for quality assurance in volunteer crowdsourcing	1	1	0	2
[75]	Rules of crowdsourcing: Models, issues, and systems of control	1	1	0	2
[76]	Skills and wills: The keys to identify the right team in collaborative innovation platforms	1	0	1	2
[77]	Task design, motivation, and participation in crowdsourcing contests	1	1	1	3
[5]	Toward an understanding of participants' sustained participation in crowdsourcing contests	1	1	0	2
[20]	Crowdsourcing: A review and suggestions for future research	1	1	0	2
[7]	Of crowds and talents: Discursive constructions of global online labor	1	1	1	3
[78]	The ethical use of crowdsourcing	1	1	0	2
[79]	A transfer learning-based framework of crowd-selection on twitter	1	0	1	2
[25]	Crowd build: A methodology for enterprise software development using crowdsourcing	1	1	1	3
[80]	CrowdEval: A cost-efficient strategy to evaluate crowdsourced worker's reliability	1	1	1	3
[26]	CrowdSelect: Increasing accuracy of crowdsourcing tasks through behavior prediction and user selection	1	0	1	2
[81]	December: A declarative tool for crowd member selection	1	0	1	2
[82]	Declarative user selection with soft constraints	1	0	1	2
[1]	Optimal task partition with delay requirement in mobile crowdsourcing	1	1	1	3
[83]	TDSRC: A task-distributing system of crowdsourcing based on social relation cognition	1	1	1	3

in gaining the rewards that are associated with tasks and thus do not work sincerely, and this is a negative factor of the crowd [29]. They act selfishly (negative feature) for utility utilization [18]. Workers may act maliciously [35, 80, 83],which limits the quality of tasks, or may be "eager beavers" [35] who outperform appropriate workers [5]. Trainees may accomplish tasks [3, 41] in the crowdsourcing activity. The crowd may be autonomous [34], fast [2] unique [69], appropriate [3], right [28, 79], reliable/efficient [2, 25, 72, 73, 80], loyal [70], truthful [36], trustworthy [29, 42, 44, 50, 63] who complete assigned tasks sincerely. Workers are coordinative, adaptable [16] (as they can change themselves with the change in the work environment), "Energetic" having energy [10, 17], capable [1, 42, 60] of performing tasks, and are "creative" as they creatively [67, 68, 78] perform different types of work. They are competent workers [16, 39, 63] who utilize common sense [68] in various tasks. Crowds are smart [25, 27], educated/qualified [1, 13, 42], professionals [71, 75], having skills (skillful workers) [2, 8, 10, 12, 14, 17, 26, 28, 37, 48, 51, 54, 56, 57, 59–61, 67, 76–78], expertise [58, 59, 81, 82], experience [14, 17, 19, 24, 43, 46, 47, 53, 76] who possess knowledge [2, 8, 11, 13–15, 17, 19, 22, 30, 35, 38, 49, 55, 60, 61, 68, 70, 71, 75, 76] for getting a task done [35]. Workers may be cooperative [12], collaborative [21, 39, 76]. Crowds may work as volunteers [10, 15, 17, 74–76] for solving large problems [5, 7, 21, 54, 60, 64, 68, 75, 78], i.e., they are solution providers [5]. Workers can make decisions [15].The various features of the crowd are represented in Table 6 and Table 7.

3.3. Reasons behind Crowd Participation (RQ2). Various incentive measures are adopted to motivate participant for contribution like for teams in organizations, pointing system is adopted and participants are provided with different points depending on their performance level. These points are then converted into prizes and gifts. External participants are provided with honoraria and likelihood of career prospects/advancement [14, 19, 20, 41] and being employed in future work [71]. Various workers complete different types of tasks such as sentiment analysis and tagging of image, solving microprogramming tasks in order to receive benefits of remuneration [2, 19, 41, 56] financial [6], monetary [41, 47, 83], reward [37, 78], prize [36, 37, 49, 71, 78], payment [45, 65, 66] like immediate payoffs (making money) [5], cash [50, 75], fee [57], direct compensation [16, 31, 61, 66] and money [8, 55], extra bonuses [12, 35], extra income [43], non-monetary awards including delayed payoffs (the potential to take freelance work) [5], status [3], pleasure personal enjoyment/fun [5, 62], and for learning purpose [6, 45] to increase their

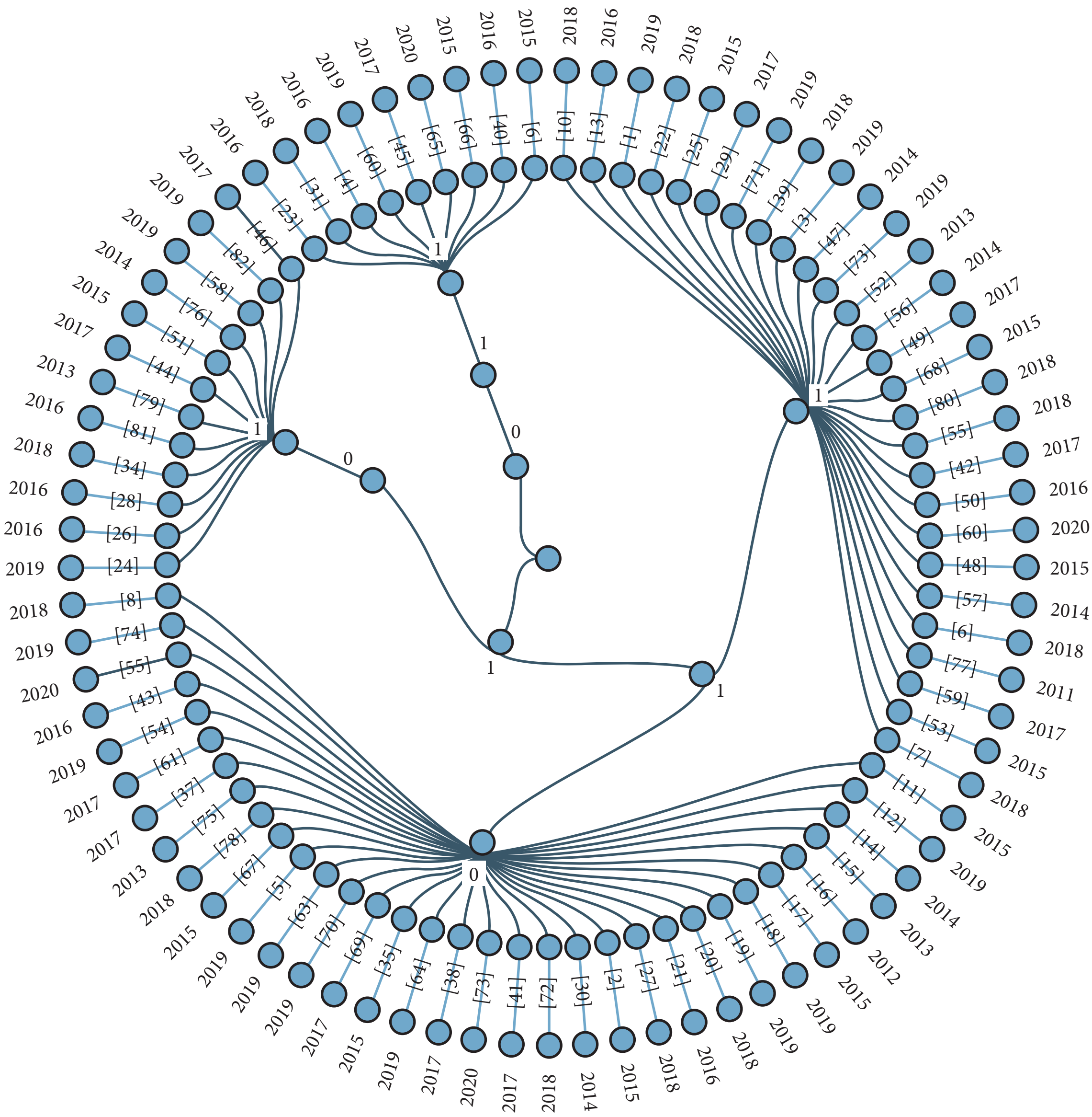

Figure 5: Quality of assessment chart of the selected papers.

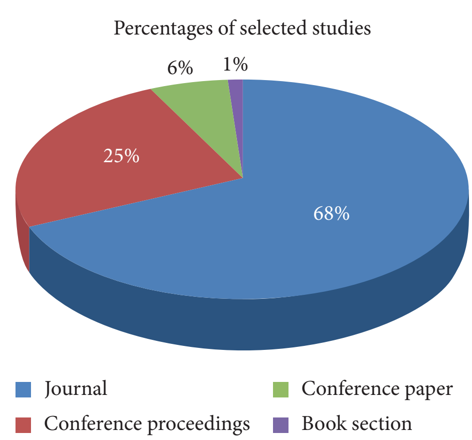

Figure 6: Percentages of selected studies.

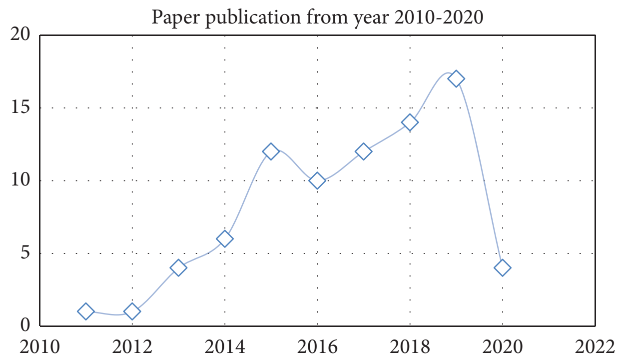

Figure 7: Number of selected papers based on publication year.

Table 6: Negative features/characteristics of crowd workers.

S. no.	Negative features	Citations
1	Nonprofessionals	[49, 56, 83]
2	Nonexperts	[49, 68]
3	Untrustworthy	[29]
4	Unskilled workers	[48]
5	Anonymous	[3, 6, 7, 11, 19, 73, 83]
6	Untrained participants	[3, 35]
7	Malicious workers	[35, 80, 83]
8	Selfish workers	[18]
9	Novice	[12, 20, 41, 47]
10	Transient workers	[83]
11	Inexperience	[11]
12	Fraudulent	[1]
13	Incompetence	[21]

knowledge [15–17], increase reputation [65, 77] in public display by increase in point and badges. The motivation may be an introjected one in which crowd participates for recognition [6, 62] among peers, fame [37]. People also compete with each other to develop their skills [6, 45]. Crowds are rewarded based on the quality of the completed task. A worker who produces quality results is awarded with incentives [35, 37] and access for future work [8, 43]. Worker observes developers [15] work, raise, and collecting funds [12, 49, 53, 75] for projects. Crowd also participates for inspiration [49] from other solutions and revision of solutions for generating better alternative [3, 17] for existing solutions. Communication [39, 53] with each other to manage their time [39] is also a reason for participation. Crowd works in cooperation [15, 20] and in collaboration [12, 53] for improving products. Crowd participants may also participate to provide ideas [12, 53] for various developmental projects. A participant participates as he/she perceives curiosity [12, 60, 77], self-affirmation [60], self-estimation [6, 78], and appreciation [49] of requester organizations. Workers are motivated for self-marketability [41, 77], visibility [7]. Self-efficacy [20, 41, 54] which constitutes four types of incentives, namely, accomplishment [12, 40, 41] (workers feel that they are accomplishing something while participating in tasks), importance (workers observe that their doing is important to others), competence [41] (working on crowdsourcing tasks provide a wisdom of competency), and doing best job (workers desire to know that they are doing best), and to contribute. There are four incentives regarding contribution, namely, effectiveness (how effective the tasks are to others), helping others (participant completes the task to help other people), trust (workers are trusted by organizations), and supporting others (participants support each other in the accomplishment of tasks) [41]. The crowd also participates to find an appropriate answer for a question [3, 35, 49]. An individual can be motivated to gain or share experience [12, 62] and increase his or her expertise level [59]. Other reasons for motivating the crowd to participate in tasks are volunteering (free contribution) [6, 10, 74], reciprocity and expectancy in which users participate for intellectual stimulation [2]. To help a community as they expect that others will also contribute in society [2, 41, 77], contribution of each every one will help in solving a community problem. Crowd contributes altruistically [9] without greediness/expectations for something; they do it out of sympathy, which is known as altruism [62]. There are also some factors that motivate the crowd for participation like making new friends [16] and for socialization [54, 70] purposes; people also contribute in crowdsourcing as they have interest in [16, 60, 65] a field. Developers for task are motivated by ideology, self-need, self-development, and for preserving authorship of their own work to get paid to provide best solutions to problems [39]. Crowds may provide a service [2, 40], acquire information [40, 62], or may accomplish a task like booking a table in a restaurant [40]. Contestants also participate so that organizations provide them feedback [47, 55] on their completed work. The crowds are motivated by means of intrinsic and extrinsic motivation [77] Intrinsic motivation is concerned with participation that increases interest and joy due to which participant feels competency, fulfillment, and satisfaction [12, 61]. Extrinsic motivation is working on something that provides some distinguishable results. It involves engagement because of external incentives such as compensation [66]. The participation may be due to identifiable motivation, which is a reaction of freedom and violation since the deeds are concerned with identity and personal goal achievements [61]. Integrative motives [60] may be a cause of participation in which participant activities are considered significant and meaningful. The crowd is also motivated by networking motives for building professional or personal relation [17, 60]. This will increase self-belonging [60] and increase engagement. Self-marketing [41, 60, 77] or self-advertisement [60, 61] is a major motivation for participation in projects for individuals looking for a job. Workers perceive that competition provides workers with a number of benefits, and they have to show eagerness to engage in competitions [15, 16, 61]. Workers are willing to participate as they are provided with task autonomy [61]; participants are offered a high level of control on their actions in competition. Task variety is another motive for participation where a participant is allowed to provide solutions from different viewpoints. Players are allowed to use their abilities and skills for developing solutions. Task

Table 7: Positive features/characteristics of crowd workers.

S. no.	Positive features	Citation
1	Professionals	[71, 75]
2	Expertise	[58, 59, 81, 82]
3	Trustworthy	[29, 42, 44, 50, 63]
4	Skill	[2, 8, 10, 12, 14, 17, 26, 28, 37, 48, 51, 54, 56, 57, 59–61, 67, 76–78]
5	Identifiable	[34]
6	Autonomous	[34]
7	Flexible	[34, 81]
8	Creative	[67, 68, 78]
9	Common sense	[68]
10	Knowledge	[2, 8, 11, 13–15, 17, 19, 22, 30, 35, 38, 49, 55, 60, 61, 68, 70, 71, 75, 76]
11	Appropriate	[3]
12	Eager beavers	[35]
13	Trainee	[3, 41]
14	Competent	[16, 39, 63]
15	Adaptable	[16]
16	Coordinative	[16]
17	Heterogeneous	[38, 52, 56, 64]
18	Collaborative	[21, 39, 76]
19	Decision maker	[15]
20	Qualified/educated	[1, 13, 42]
21	Ability	[1, 42, 60]
22	Problem-solving	[5, 7, 21, 54, 60, 64, 68, 75, 78]
23	Unique (workers)	[69]
24	Volunteers	[10, 15, 17, 74–76]
25	Energetic	[10, 17]
26	Experienced	[14, 17, 19, 24, 43, 46, 47, 53, 76]
27	Reliable/efficient (workers)	[2, 25, 72, 73, 80]
28	Accurate	[74]
29	Smart	[25, 27]
30	Cost-effective workers	[72]
31	Solution providers	[5]
32	Right	[28, 79]
33	Fast	[2]
34	Cooperative	[12]
35	Truthful	[36]
36	Inventive	[64]
37	Loyal	[70]

complexity is another motive for participation as task is complex; its completion requires high competency, skills. Workers are interested in performing complex tasks to gain self-expression and a sense of competency. The crowd also participates for sponsoring an organization [61]. The crowd also shares and acquires information [40, 62], recommends [62, 75] some things, shares life experiences, provides suggestion, and increases the level of ranking [62]. Crowd teams participate in crowd source task for receiving tangible (monetary) and intangible (reputation) rewards, for social comparison (self-evaluation with others) [54]. Co-creation, or working as mediators for crowd acquisition, task specification, and evaluating outcomes, advocating, and co-development [70] are also motives for the crowd to participate in activities. Expectations [78] of earning profit such as "Cambros," credit point, selling digital pictures online, voting things, scoring, commenting, decision-making, sharing reviews about a product [75] are also the reasons for crowd participation. Virtual teams complete tasks for bringing social capital [16, 17] (relationship) to their teams. The crowd also participates to brainstorm ideas and to agree about certain activities for alternative [3, 17] solutions [17, 39, 53, 60]; crowd workers are encouraged to participate as they are considered meaningful or relatedness as compared with others in the community [12]. The crowd contributes for detecting and correcting errors, and they desire to satisfy standards [21]. Membership, efficacy, reciprocity, etc., may be the reason for participation [20]. The reasons for crowd participation are represented in Table 8.

3.4. Existing Techniques Used for Crowd Selection (RQ3)

3.4.1. Profile-Based Searching. Profile [40] is an identity of crowd workers. In the registration process, crowd workers have to express themselves by posting personal profiles. Workers are selected for different projects [7] using profile data. Information about age, sex, and ability of workers to perform tasks is present in the profile [40]. Profile captures properties, sets, and describes participant name, location,

Table 8: Presentation of various reasons for crowd participation.

S. no.	Reasons of participation	Citation
1	Honoraria	[71]
2	Future employments/work	[8, 35, 37, 43, 60, 71, 72, 77]
3	Enhancing performance	[12, 71]
4	Money	[8, 16, 23, 27, 29, 41, 43, 48, 52, 55, 56, 60, 61, 68, 77]
5	Payment	[3, 4, 6, 7, 11, 13, 18, 19, 35, 37–39, 45, 64–66, 72, 73, 80]
6	Cash	[50, 75]
7	Entertainment/fun/enjoyment	[5, 6, 11, 12, 15, 16, 37, 41, 54, 60–62, 68, 70, 72, 78]
8	Skills development	[6, 8, 15, 17, 22, 27, 41, 45, 47, 49, 61, 68, 77, 78]
9	Reputation	[16, 17, 22, 35, 54, 65, 68, 77]
10	Gaining/sharing knowledge	[6, 11, 15–17, 21, 49, 53, 60, 61, 70, 75, 78]
11	Prize/reward	[36, 37, 49, 71, 78]
12	Funds collection	[12, 49, 53, 75]
13	Finding answers to questions	[3, 35, 49]
14	Inspiration	[49]
15	Education/learning	[6, 12, 15–17, 19, 20, 35, 37, 45, 47, 49, 60, 70, 72, 77]
16	Appreciation	[49]
17	Incentives	[11, 35, 37, 52]
18	Recognition	[6, 11, 14, 37, 41, 52, 60–62, 75, 77]
19	Fame	[37]
20	Gaining and sharing experiences	[12, 17, 27, 39, 41, 53, 60, 62]
21	Altruism	[12, 16, 38, 62, 77]
22	Rewards (monetary/nonmonetary, economical)	[1, 3, 13, 14, 16, 17, 20, 25, 30, 41, 42, 45, 47, 54, 55, 59, 60, 62–64, 69, 70, 75, 77, 78, 83]
23	Friendship	[16]
24	Socialization	[5, 8, 11, 12, 16, 20, 54, 70]
25	Gaining and sharing idea/ideology	[12, 17, 20, 38, 53, 60, 75, 80]
26	Self-need	[38]
27	Self-development	[38]
28	Authorship	[38]
29	Increasing utility	[18]
30	Extra bonus/income/points	[12, 18, 23, 35, 71]
31	Compensation	[16, 31, 61, 66]
32	Extrinsic and intrinsic rewards/needs	[5, 6, 12, 14, 20, 21, 60, 67, 77]
33	Self esteem	[6, 16, 78]
34	Voluntary participation	[6, 10, 74]
35	Well-being/love of community, intellectual stimulation	[2, 5, 6, 8, 10, 11, 16, 41, 77]
36	Communication	[39, 53]
37	Cooperation	[15, 20, 72]
38	Collaboration	[12, 15, 49, 53]
39	Competition	[15, 16, 61]
40	Remuneration	[2, 19, 41, 56]
41	Career perspective	[14, 19, 20, 41]
42	Provision of services	[2, 40, 62, 80]
43	Sharing and acquiring information	[40, 62]
44	Accomplishing task	[12, 40, 41]
45	Self-marketability	[41, 60, 77]
46	Pleasure	[41]
47	Self-efficacy	[20, 41, 54]
48	Contribution/sharing work	[41, 60]
49	Earning extra income	[43]
50	Providing or gathering feedback	[47, 55]
51	Fee	[57]
52	Enhancement of expertise level	[59]
53	Integrative motivation	[60]
54	Self-advertisement/self-expression	[60, 61]
55	Individuals are free to performing tasks, i.e., task autonomy	[61]
56	Social comparison	[54]
57	Self-evaluation	[54]
58	Sponsorship	[61]
59	Achievements of goals	[61]

Table 8: Continued.

S. no.	Reasons of participation	Citation
60	For recommendation	[62, 75]
61	Suggestion	[62]
62	Financial benefits/rewards	[6, 11, 22, 25, 41, 62, 63, 73, 78]
63	Ranking	[62]
64	Solution	[17, 39, 53, 60]
65	Tangible and intangible rewards	[54]
66	Satisfaction	[12, 21, 60, 61, 70]
67	Co-creation	[70]
68	Co-development	[70]
69	Crowd acquisition	[70]
70	Advocating	[70]
71	Specifying tasks	[70]
72	Evaluating outcomes	[70]
73	Earning profit	[75]
74	Cambros	[75]
75	Credit points	[75]
76	Selling	[75]
77	Voting	[75]
78	Scoring	[75]
79	Commenting	[75]
80	Sharing reviews	[75]
81	Decision-making	[17, 75]
82	Gaining social capital	[16, 17]
83	Brainstorming	[17]
84	Finding alternative solutions	[3, 17]
85	Altruistic contribution	[9]
86	Financial and nonfinancial motives	[7]
87	Immediate/delayed payoffs	[5]
88	Importance	[41]
89	Competence	[8, 12, 41, 60, 61]
90	Best job performer	[41]
91	Trusted	[41]
92	Interest	[16, 60, 61, 65]
93	Curiosity	[12, 60, 77]
94	Self-affirmation	[60]
95	Professional and personal relation	[17, 60]
96	Self-belongingness	[60]
97	Meaningfulness	[12]
98	Relatedness	[12]
99	Self-development	[12]
100	Membership	[20]
101	Reciprocity	[20]
102	Visibility	[7]
103	Task variety	[61]
104	Task complexity	[61]
105	Expectation	[78]
106	Detect and correct errors	[21]
107	Desire for satisfying standards	[21]

etc., using ontology-defined vocabulary [82]. Workers' attributes [68] and trust factor are present in the profile [34]. Personality-trait-based tool on various profiles is used to select workers [71]. Profiling will help in personalization of the intelligent decision and enhances the quality and selection of appropriate workers (crowd) for tasks. Personalization of crowd members would improve the decision quality [57].

3.4.2. Selection on the Basis of Skill Assessment. Skills assessment is used for evaluation and certification of worker reliability to assist in the job matching process. Organization offers certification, which certifies that a worker has relevant skills [3, 7, 25, 31, 47, 49, 51, 52, 60, 76, 83]; these certifications are then used for recruiting purpose [51]. Workers who possess required skills are assigned tasks [3]. Skill evolution mechanism may be adopted for giving a chance to prove skills [52] Varieties of skills are needed from general, to specific, to situational [60]. Initial screening of the crowd is carried out based on skills [49] that are required for completing a task [25].

3.4.3. Expertise Filtering. Expertise [3, 9, 13, 31, 46, 49, 58, 68, 71, 79] filtering is carried out to check the expertise level of workers. Expertise-estimation approaches estimate the expertise of workers [58]. The right crowd is selected based on their expertise level [68, 79]. Workers are assigned to a task if they have expertise in the required field [3]. As an individual has expertise in the task, he or she will try to complete it with full attention [31]. It depends on task relevance and diverse expertise, and the level of participant selected [46].

3.4.4. Selection on the Basis of Crowd Attributes, Behaviors, and Attitudes. There are various attributes of crowd workers [68] which are significant for value match [31]. Attributes may be social [36], which shows crowd online or offline status, and social activities of workers assist in understanding routine behaviors [53]. Workers' behavior is noticed when they complete tasks and bear a definite behavioral pattern [26]. Agent-based (AB) technique is applied to identify behaviors of crowd workers individually and to analyze the diverse attribute of participants. Workers are represented as agents and they have various characteristics. At platform, these agents arrive in nonhomogeneous passion distribution which are assigned with unique IDs based on their characteristics specified with utility factor which show their behaviors. An agent has a decision-making state that consists of two components, i.e., registration and submission of tasks. Agent decision is related to information that is received from agent's community and social environment, and from other competing agents. The agent is responsible for submitting the task, and upon submission his or her attributes for reliability factor are updated [34]. The positivity of the crowd worker attitude increases their interest in solving a task [57].

3.4.5. Selection on the Basis of Trustworthiness. Trust is the main factor for selecting workers for a task [3, 9, 29, 48]. A requestor may recruit trustworthy crowd workers [9]. For identifying trustworthy workers, SSC (Strong Social Component) and C-AWSA (Context-Aware Worker Selection Approach) is used, which is an efficient and valuable algorithm for selecting trustworthy workers. For optimization purposes, quality of trust as well as path utility is used. Forward searching Algorithm is used to calculate the trustworthiness of a worker [29]. Trust-Based Access Control (TBAC) strategy is utilized for computing trust value. Fuzzy Inference System evaluates the trust values and based on these values, access for a task is granted to crowd workers. The discrete model is used to decide whether an entity is trustworthy or not [48]. Trust factor of agent is updated when he or she submits a task [34]. "Career ladders" may be generated for trusted workers by organization for participating in high-level assignments [31]. Trustworthy workers are placed at a higher level [47].

3.4.6. Selection on the Basis of Performance. Crowd workers are selected according to past performance [42] in various tasks [6, 68]. Worker previous task registration and winner records [49] are necessary for assigning tasks. The workers' performances may increase with training [31]. For dealing with unknown worker performance in multiarmed bandit (MAB), initial exploration phase consistently samples the performance of workers using budget, and in the exploitation phase best workers are selected [56]. Affinity values can be calculated by participants' social attributes and their previous task execution record [36]. Crowdsourcing platform is concerned with monitoring workers for evaluating and updating their skills depending on the quality of the tasks completed in the past [47]. December uses previous records of members of a crowd [81] from previous activities or social networks [82] for selection.

3.4.7. Selection on the Basis of Feedback. The crowdsourcing platform gives feedback (temporary ranking) to crowd workers and based on these feedback, workers decides to quit or to compete for performing a task [3]. Feedback is increased or decreased while working [68].

3.4.8. Role-Wise Selection. Roles assigned to crowd workers change with the change in the crowdsourcing environment [48]. Flash organization selects a crowd automatically, as they are structured in hierarchical form according to their roles and responsibilities [3].

3.4.9. Selection on the Basis of Bid. Crowd workers are selected on the basis of winning bids. These workers make a bid based on their calculated effort and cost for getting a task. Only workers with winning bids are selected to submit a solution of the task [3]. Workers are selected statically, and after bidding winners are selected dynamically [50]. Workers with lower bids are hired first. Each new bid must satisfy the affinity and ability constraints. In the process, the winning bid gets the payment from the platform. For carrying out decision by platform, the users wait and stay online, and they may report dishonest time of entrance or exit in order to exploit their service. They may postpone their bid time and confer a prior exit time. During the time new challenges arise bid-independence, a user's payment cannot be affected by its bid, and the real appearance/exit time of the participant should not be known and is submitted truthfully. For the subsequent challenge, every active bid will contribute in the auction and their payment will be updated [36]. Classical bid auction was extended for ensuring quality [52].

3.4.10. Selection Based on Job/Qualification Tests. Requesters specify requirements for workers to participate in activity. These requirements may consist of various tests that a participant has to complete in order to qualify for a job [68]. Workers are judged through qualification [3]or through job test [31]. Workers must pass qualification test before participating in tasks/projects [6]. Qualification test will ensure that worker has the knowledge for designing the user interface. Workers were selected based on the score achieved in the qualification test [4]. Requestor selects workers based on fulfilling some qualification requirement [66].

3.4.11. Time- and Constraints-Wise Crowd Selection. Workers are encouraged to appear on time [50]. Crowds are registered, requirement of requestors are analyzed, time and duration is decided, and an appropriate crowd is selected [3]. Task agent announces an open call with instruction to available workers who will fulfill precise conditions. The task agent receives a reply from participants that are willing. A favorable set of workers is selected based on time constraints. Subsequently, it transfers a confirmation to the selected worker [40]. Requestors divide a complex task into subtasks, which increases the task probability of workers to accept the task in a specified time [1]. Participants are selected on the basis of timeliness of workers in prior accomplished tasks [9].

3.4.12. Selection on the Basis of Belt Level. Workers are grouped in the registration order into five different belts, i.e., red, green, yellow, blue, and gray, which represent the skill level of workers. Reliability of workers is measured by registration and completion of the submitted task [44].

3.4.13. Crowd Selection on the Basis of Experience Level. Crowd from a large pool of people are selected on the basis of experience [7, 45] of at least two years [24]. Experience strategy is developed for selecting experienced workers (testers) who have reported many bugs in the past [46]. Leader of a team is selected according to his or her previous experience [22].

3.4.14. Ranking System Used for Crowd Selection. A ranking system was proposed, which dynamically modifies the worker skills. In ranking systems, trustworthy workers are placed at a higher level and others at a lower level. Workers are ranked in three categories, i.e., new comers, associates, and seniors. Ranking allows platforms to automatically find an appropriate worker for a specific task [47].

3.4.15. Task Assignment Technique for Crowd Selection. For selection of qualified workers for sensing task, various task assignment techniques are applied. In MCS, worker selection is a challenging issue and it affects the sensing efficiency and quality. Various criteria are adopted for filtering the unsuitable worker. The task assignments framework consists of participants who use sensors for obtaining or measuring required data about his or her interested subject. Application/end users request with data through task and utilization of information required by participant, tasking entities distribute task to workers [62].

3.4.16. Crowd Selection on the Basis of Capability/Ability. Organizations select employees who have the capability to produce great and diverse ideas for solving technical problems [71]. The organization makes a decision to preasses the ability of a crowd to perform complex tasks [66]. A worker is selected on the basis of ability [1]. The Borda ranking algorithm is utilized to check capability for selecting participants for the accomplishment of a dynamic task [23].

3.4.17. Demographic Filtering for Crowd Selection. Crowd workers have different demographics [42, 46]. Demographic filtering selects specific country/location people [6, 68]; workers are selected according to their demography [22]. Workers provide information about demography if they are willing to participate in tasks [4].

3.4.18. Crowd Selection on the Basis of Availability of Workers. Workers transfer messages to ensure their availability [40] or online status [36] on platform. Tasks are successively posted to a pool of workers [80]. Workers' characteristics are identified for analyzing the availability of workers to perform and complete tasks [44]. Workers are assigned with tasks based on their availability [13].

3.4.19. Recommendation-Based Crowd Selection. For a project, appropriate workers are recommended [10, 71]. The recommendation system is used to assess the crowd [28]. Workers are ranked according to recommendation levels [48]. For guiding workers to perform suitable tasks, recommendation techniques are used [49]. The recommendation system helps crowd workers in finding related tasks [39].

3.4.20. Screening-Based Crowd Selection. Initial screening of the crowd is carried out based on skills that are required for completing a task [25]. Workers must pass an initial prescreening exam that consists of gold tasks. Prescreening assists requesters in inferring worker's reliability [80].

3.4.21. Relevant Background Filtering for Crowd Selection. A crowd is selected from diverse sources and with various backgrounds [60]. In some crowdsourcing activities, crowd workers' recruitment is restricted to only workers who have declared that they have a relevant background [24].

3.4.22. Crowd Selection on the Basis of Reputation. For checking the suitability of workers, their reputations are checked [9]. The reputation system calculates the reputation score of online workers based on collective ratings of employers that had hired them for tasks in the past [51]. A truthful online reputation updating algorithm was proposed for updating workers' reputation [50]. Reputations of registered workers are checked before their participation in tasks. After the submission of tasks, quality is determined as it is used to control the reputation [65].

3.4.23. Selection of Crowd on the Basis of Rating. Rating was used as important measure for generation of participant profiles. Workers are assigned only those tasks which were suitable for them [52]. Ratings assist in selecting an appropriate candidate for tasks [25].

3.4.24. Crowd Selection on the Basis of Incentives/Reward Mechanisms. Incentive mechanism was proposed for worker selection. Workers are selected statically, and after bidding, winners are selected dynamically [50]. Participant incentives' requirements are considered for selection [23]. Tasks are assigned to crowd based on associated reward [13].

3.4.25. Crowd Selection on the Basis of Voting Scores. Task requester selects workers based on some criteria such as majority voting [26, 71].

3.4.26. Crowd Selection According to Social Relation of Workers. A worker having high social context values is selected [29]. For distributing tasks in friends without getting their information, social relationship is utilized in the process. "A Task-Distributing System of Crowdsourcing Based on Social Relation Cognition, TDSRC"only accommodates interaction information of requestor and friends. Using social relationships, the model builds a trust chain among requestors and solvers, and thus increases the reliability of task distribution [83].

3.4.27. Crowd Selection on the Basis of Auction. Organizations utilize auction-based model for the selection of crowd workers based on their skills, qualification, and trustworthiness [3]. Classical bid auction was extended for ensuring quality. Appropriate workers are invited and the bids are ranked for specific rewards [52].

3.4.28. Crowd Selection on the Basis of Matching Mechanism. Matching of task to appropriate workers should help the crowd to spend their strength in tasks to benefit the crowd as well as organization [31]. Task and tester matching technique is used to select a crowd (testers) from a large pool of people [45]. Project managers use a matching method to select the leader of a team [22]. The existing techniques for selecting an appropriate crowd for tasks are represented in Table 9.

4. Research Findings

The crowdsourcing activity involves allocation of tasks to the Internet crowd [2, 39]; with an open call, the crowd is involved in solving tasks that are complex. These crowds are employed from web-enabled communities. Crowd workers represent some attributes, such as qualification, age, gender, language, worker location, skills, past service, and experience. Workers are selected on the basis of these attributes [13, 17, 40, 45]. Crowdsourcing assists workers or an organization to seek services, contents, ideas, or services from a huge group of people online (crowd) [80]. The crowd workers are dynamic and creative, with a variety of motivations and experiences. Unique crowd workers' participation is required in crowdsourcing. Global workers have to represent themselves as experts by posting personalized profiles created during the process of registration [7, 69]. Information of workers, such as sex, age, and ability, is present in the worker profile [40]. The crowd is evaluated on the basis of the work performed [22]. An appropriate set of workers is selected for performing tasks [46]. For achieving quality outcomes, an employer should carefully select workers [56]. The quality provided by workers depends on the distribution of tasks to the members of the crowd, which requires appropriate mechanisms to be controlled such as by screening workers [13, 42]. Initial screening of the crowd is carried out on the basis of skills required to complete a task. Care must be taken while selecting the crowd, as it is noticed that the quality improves with a diverse crowd selection [25]. Quality outcomes produced by crowd workers depends on certain aspects such as worker skills, their experience regarding tasks, and their commitment for performing tasks [47].

5. Discussion

The analysis highlights the point of view behind research in the area of crowdsourcing and provides a synopsis of current crowd selection techniques based on certain aspects. Crowd selection is an important phase in crowdsourcing. With the help of selection methodologies, the appropriate participant for a task is selected. The review has a number of implications in the crowdsourcing activity. In the crowdsourcing activity, the task is performed by crowd workers. The study highlights the multi features of an online crowd in order to choose the right candidate for a task from Internet communities. The review also underscores as to why crowds participate in crowdsourcing tasks? Various techniques were suggested in literature for crowd selection. They are represented in this review for the purpose of understanding how the crowd was selected previously and to identify the measures for this selection process.

6. Validation Threats

The biased nature of publications and extraction of inaccurate data are considered as major threats regarding review protocol. The studies are selected on the basis of search string, described in the search strategy, which includes literature resources, selection on the basis of criteria, and quality assessment criteria. Search string relevant to specific formulated questions was used for the extraction of relevant studies. However, there might also be some

Table 9: Existing technique used for crowd selection.

S. no.	Description	Existing techniques	Citation
1	Workers are selected according to personal profiles that contain various attributes such as sex, age, workers' ability, demography, expertise, experience, past performance, etc.	Profiling-based selection	[7, 39, 40, 42, 47, 49, 52, 57, 59, 68, 69, 71, 76, 81, 82]
2	For accomplishment of tasks, crowds are selected according to their skills related to various tasks. Skills test assessments are carried out to certify that workers have the necessary skills for completing tasks.	Skill assessments	[3, 7, 25, 31, 47, 49, 51, 52, 60, 76, 83]
3	Expertise-based selection is carried out to capture experts to perform specific tasks.	Expertise filtering	[3, 9, 13, 31, 46, 49, 58, 68, 71, 79]
4	Behavior and attributes are important characteristics of workers participating in various tasks. Workers are selected on the basis of their attitude and behaviors observed in performing various tasks.	Selection on the basis of crowd attributes, behaviors, and attitudes	[26, 31, 34, 36, 53, 57, 68]
5	Trust is an important factor for the selection of the appropriate worker for tasks. Workers are assigned with different trust values and they are selected based on these trust values.	Selection on the basis of trustworthiness	[3, 9, 29, 31, 34, 47, 48]
6	Individuals are selected based on their previous or current performance in different types of tasks.	Performance	[6, 36, 42, 47, 49, 56, 68, 81, 82]
7	Feedback is provided to rank workers for competing or quitting various tasks; crowds are selected on the basis of various feedback provided by third parties, i.e., organizations or other participating bodies.	Feedback mechanism	[3, 68]
8	Workers are selected on the basis of their roles.	Role-wise selection	[3, 48]
9	Workers are allowed for making their bid, and appropriate workers are selected according to their bid level to perform a task. The bids are associated with specific rewards.	Selection on the basis of bid	[3, 36, 50, 52]
10	Organization conducts qualification- or job-specific tests to assess and select workers for various types of tasks. Qualification test ensures that workers have relevant knowledge for the task.	Selection based on job/ qualification tests	[3, 4, 6, 31, 66, 68]
11	Optimal set of workers are selected based on time and cost constraints. Workers are selected on the basis of timeline followed in previous completed tasks.	Time and constraints	[1, 3, 9, 40, 50]
12	Workers are grouped in registration order into five different belts, i.e., red, green, yellow, blue, and gray, that represent the skill level of workers.	Selection on the basis of belt level	[44]
13	Crowd participants are selected on the basis of their experience level.	Crowd selection on the basis of experience level	[7, 22, 24, 45, 46]
14	For worker selection, ranking is applied. Workers are classified into three categories, i.e., new comers, associates, and seniors. Ranking allows platforms to automatically find out an appropriate worker for a specific task.	Ranking	[47]
15	In mobile crowd sensing, task assignment techniques are used to select crowd workers. The task assignments' framework is used to capture participants who use sensors for obtaining or measuring specific data.	Task assignment technique	[62]
16	A worker is selected on the basis of his or ability and capability toward a task.	Crowd selection on the basis of capability/ Ability	[1, 23, 66, 71]
17	Candidates are selected according to their country of origin.	Demographic filtering	[4, 6, 22, 42, 68]
18	Before allocation of task to workers, their availability on platforms is observed.	Crowd selection on the basis of availability of workers	[13, 36, 40, 44, 80]
19	For assessing the crowd capabilities, a recommendation system was utilized. Crowd workers must have access to the recommendation system to help them in finding related tasks according to their profiles.	Recommendation-based crowd selection	[10, 28, 39, 48, 49, 71]

Table 9: Continued.

S. no.	Description	Existing techniques	Citation
20	Screening of the crowd is carried out based on skills that are required for completing a task. Workers are screened out from a diverse group by conducting tests, etc.	Screening-based crowd selection	[25, 80]
21	Crowd workers' recruitment is restricted to only workers who have declared that they have a background to a specific task and if they possess a working history of at least two years.	Relevant background filtering for crowd selection	[24, 60]
22	The reputation system is used to select participants on the basis of their level of reputation.	Crowd selection on the basis of reputation	[9, 50, 51, 65]
23	The crowd is rated based on the quality of responses. Rating assists in selecting the appropriate crowd for tasks. Workers are selected by job seekers according to their rating.	Selection of crowd on the basis of rating	[25, 52]
24	An incentive mechanism was proposed for worker selection. Workers are selected statically; after bidding, winners are selected dynamically	Crowd selection on the basis of incentives/ reward mechanisms	[13, 23, 50]
25	The task requester selects workers based on some criteria, such as majority voting, for estimating correct answers of a task.	Crowd selection on the basis of voting scores	[26, 71]
26	Social relationship among requestors and solvers is established and the task is given to friends of a friend; due to this, the reliability of task distribution is increased.	Crowd selection according to social relation of workers	[29, 83]
27	Matches complex tasks requiring multiple skills to appropriate workers. Workers are invited for making a bid for a task, and this bidding was based on price as well as worker profile.	Crowd selection on the basis of auction	[3, 52]
28	To select a crowd (testers) from a large pool of people, the technique was used. The tasks are matched with crowd and only the appropriate crowd is permitted.	Crowd selection on the basis of matching mechanism	[22, 31, 45]

irrelevant studies that are extracted using search strings. A selection criterion was adopted in compliance with formulated questions to extract relevant studies. Finally, the studies are evaluated on the basis of the quality of assessment, and these papers are analyzed thoroughly to minimize the threats linked with the extraction of inaccurate data.

7. Conclusion

In the proposed study, we addressed the problem of crowd selection in crowdsourcing. One of the key contributions of our research is to illustrate the various multiple features of the crowd. Another contribution of the review is to identify the various reasons of crowd participation, and the third contribution of this study is to capture various selection methods used for crowd selection. Research aims are extracted from various studies in the literature. The aims are extracted from online data repositories such as IEEE, ACM, ScienceDirect, Taylor & Francis, Wiley, Hindawi, and Springer. They were searched on the basis of search strings to extract relevant studies.

Our preliminary objective was to capture the current state of crowd selection in crowdsourcing research and to assist developers and researchers to highlight what has been done in the literature. The review points out the multi features of the crowd, reasons for participation of the crowd for engagement in various tasks, and the different techniques used for the selection of an appropriate candidate for tasks. A systematic review was conducted, and a total of 81 relevant studies are selected based on QoA. Subsequent to study selection, on the basis of title or abstract, the studies were properly reviewed for the purpose of acknowledging that the study answers minimally two research questions or not.

Our finding suggests that crowd selection is an important phase in the crowdsourcing activity; without proper selection of the crowd, the crowdsourcing activity will not be productive. This review will be a base study for future crowdsourcing researchers, as it highlights and explains the entity "crowd," their feature, and their effectiveness in crowdsourcing activities. The study will also be useful to the organization if they want to hire/select appropriate workers for a task. The survey can also benefit platforms, as it provides them with insight features and the motivation of crowd workers.

8. Research Limitations

The review was conducted rigorously within the limits of specified questions. As a result, 81 related studies have been listed and chosen to be able to answer at least two formulated questions effectively. The related studies are chosen from 2010 to 2020. With the paradigm shift and the complex nature of the crowd and crowd selection, however, we cannot fully guarantee that all possible studies in the proposed research have been captured. Another point of concern is that, because only papers published in English were included in this study, significant or appropriate research published in non-English journals was overlooked. Assessment was carried out for research biasness due to the strong tendency of reporting biases of the precise strength and weakness of current techniques. However, in this review, the selected studies did not include gray literature, technical reports, work in progress, and unpublished work, which may be capable of answering any research question. Title and content of various studies were analyzed in order to ensure that these studies are capable of answering the formulated research questions. The assessment criteria used in this analysis cannot guarantee that those criteria are sufficient to identify the appropriate studies.

9. Future Research Suggestions

Crowd selection is an important phase in the crowdsourcing activity; without appropriate selection of crowd workers, the crowdsourcing activity is aimless. In the literature, the crowd workers are selected on the basis of only a single feature, such as trust, performance, reliability, accurateness, experience, knowledge, skills, expertise, etc. As no multi-criteria features have been used in the past for crowd selection, multi-criteria-based crowd selection is mandatory for the success of the crowdsourcing activity.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare no conflicts of interest.

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Research Article

An Effective Quantum Genetic Algorithm Based on Drama Resource Mining Using Wireless Sensing Technology

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Wireless sensor technology has penetrated various domains of today's life and plays a vital role in the advanced technology. Numerous researchers have combined this outstanding technology with other fields such as resource mining, industry, healthcare, automobile system, gaming industry, and dramas. However, in traditional resource mining, long mining time leads to incomplete mining results along with low accuracy. In order to improve the effect of resource mining, we have proposed an effective Quantum Generic Algorithm (QGA) based on drama resource mining by using wireless sensor technology. In our proposed scheme, we have combined the RFID technology of wireless sensor with wireless network protocol stack for the purpose of collecting drama resources on the network platform. We have classified the drama resources on the network platform by using QGA based on the results of resources collection. Additionally, we have mined the semantic association features of frequent patterns of the drama resources on the platform and combined with the fuzzy attribute feature detection method. The experimental results show that this method is superior to the traditional methods in terms of resource mining time, mining results' comprehensiveness, and mining results' accuracy, which shows that this method has practical application value.

1. Introduction

Drama is derived from a Greek word that means "to do" or "to act." It is essentially a story that is acted out. And every play, whether serious or comedic, ancient or modern, conveys its tale through people in scenarios that are based on real life. Additionally, another key objective of drama is to generate a situation wherein the inferences, feelings, knowledge, and skills in education are liberated. In this connection, opera is a type of drama wherein music plays a central role and vocalists perform dramatic roles, but it differs from musical theater [1]. Opera is the product of combining Chinese opera art and TV media. The development and maturity of TV drama is the combination of TV as a modern means of communication and drama as a cultural resource [2, 3]. Drama represents the integration of resources needed to develop drama and the implementation of localization and characteristic strategy of TV drama [4, 5]. How to effectively obtain drama resources in the network platform has become a significant problem to be solved [6]. Many authors combined drama with today's modern technologies such as big data, wireless sensor technology, and artificial intelligence to facilitate human from low cost, high speed, and low data consumption.

In this regard, the authors in [7] proposed a data mining method based on FP growth algorithm to collect and extract features of power consumption information data of smart watt hour meter in operation, analyze abnormal power consumption data, apply machine learning method to learn eigenvalues, and deduce judgment threshold of power consumption abnormality; the association rule Data Mining method is used to fuse the results of independent detection, so as to realize the data mining of electricity theft. The experimental results show that this method can mine the abnormal data of power consumption in different periods, but it has the problem of long mining time. While in [8], the authors presented a data mining method for dam safety monitoring based on FP growth. After pruning the preprocessed monitoring data, priority tree is generated to mine frequent items. This method not only has the characteristics of fast mining speed and concise results, but also can compare single factor or analyze the relationship between multiple factor coupling and target variables, which provides a good idea for dam safety monitoring data mining. However, the main limitation of their work is that the results obtained by this method are not comprehensive, and there is a problem of missing data. Similarly, the authors of [9] planned a data mining method combining genetic algorithm and association rules is proposed. In their proposed work, firstly, GA crossover operator and mutation operator are improved adaptively, so that they can adjust adaptively according to the fitness value of function in the iterative process. Secondly, the improved adaptive GA is integrated into the association rules, making full use of GA's good global search ability to improve the efficiency of mining association rules with massive data. Thirdly, in order to avoid useless rules and reduce the existence of irrelevance, the intimacy degree is integrated to improve the reliability of association rules. Finally, on Hadoop big data platform, the optimized algorithm is verified by analyzing traffic data. The results show that the algorithm has the advantage of fast convergence speed, but the accuracy of data mining results is not high. In [10], a big data mining method for ocean going ship operation monitoring based on association rules is proposed. Firstly, the monitoring data source is obtained, and the data is stored in the database. Secondly, the ocean going ship operation monitoring data is preprocessed, so as to generate the ship operation monitoring big data mining model and complete the operation monitoring big data mining. The experimental results show that this method can ensure the accuracy of data mining, but it also has the problem of incomplete data mining results. All these works are facing limitations that need to be overcome.

Inspired from the current uprising of wireless sensing technology in various fields, specifically in the field of dramas, this study aims to develop a network platform wireless sensing technology for drama resource mining. The traditional methods are facing numerous problems regarding dramas such as long time mining, incomplete mining results, and low mining accuracy, so, in order to solve these problems, our proposed system provides efficient mining time and comprehensiveness of resource mining results with high accuracy by using Quantum Genetic Algorithm. In our proposed work, we have first designed a network platform to collect the drama resources; after that, we have acquired drama resource on the network platform based on wireless sensing technology by explaining its circuit diagram. We have also investigated Quantum Generic Algorithm based on our proposed drama resource mining and realized it.

The remainder of the paper consists of the following sections. We provide a list of related works in Section 2. In Section 3, we discuss our work strategy. The experimental attempt is discussed in Section 4. Finally, in Section 5, the study work's conclusion is presented.

2. Related Work

Drama is significant to a variety of academic areas, including cultural heritage transmission and multimedia repository classification and search. Tale ontologies [11–14] were proposed with two main purposes in mind: to identify story kinds and to provide an underlying model for narrative annotation. The authors used OWL to design several graphic kinds in [15]. The system employs the drama to execute case-based reasoning: provided a story plan, the system searches the drama for a plot that is comparable, calculating the semantic similarity of the provided plot to the plots recorded in the drama. In a similar vein, [16] utilizes automatic classifiers to categorize plot kinds, while the opiate system [17] creates and populates story worlds using a Proppian model of tale. A computational approach is used in [18] to create new stories in the manner of Russian fairy stories using the formal model. Several authors have questioned the extension of Propp's concept as a general story model in recent times, particularly in regard to digital media [13, 19].

One of the primary obstacles in the research on drama resource mining is resolving discrepancies between media kinds and genres. In [20, 21], the authors present the OntoMedia drama, a medium-independent paradigm that may be used in a variety of projects to document the narrative content of various media objects, spanning from written literature to comics and television drama. The logical notion of procedures, as used in SUMO, is used to reason about stories and produce storylines in [1]. Although not directly applicable to narrative frameworks, this method demonstrates the importance of proper action representation for tale characterization and annotation. Many initiatives have looked into the use of ontologies in online access to cultural material throughout the last decades. Computation ontologies, as discussed by [22], are particularly well suited to encoding conceptual models for access to digital resources and structuring the interaction between the archive and its users. The cultural Sampo initiative [23] makes a groundbreaking addition to the use of ontologies for culture and heritage accessibility. This project includes a set of domain ontologies that serve as a backdrop for exploring cultural items and monitoring their underlying relationships [24]. The system permits study of artifacts depending on their relationships with a reference tale at the narrative level; however, the story depiction is only functional for access to cultural items and is not meant as a standalone account of the narrative domain.

The authors in [25] advance the wireless sensor network coverage model by studying the operational features of the wireless sensor network. Though, it has better computational difficulty because it presents the optimization relations into the Particular Swarm Optimization (PSO). In [26], the authors planned a 2-phase system for gaining the finest energy provision technique by dealing with the game equilibrium of the design. Additionally, based on a connection model, in [27], the authors have presented a method of node optimization coverage for passive checking scheme of 3D-WSN. Currently, Quantum Optimization Algorithms have been progressively used to advance the network effectiveness of WSNs. For the purpose of improving the accuracy of positioning, the authors in [11] proposed a Positioning Algorithm based on quantum particle swarm optimization by using the parallelism of quantum computing. Though, the quality of the solution cannot be effectively improved by simply using Quantum Optimization Algorithm; therefore, there is a need to combine it with other techniques to further optimize the search capabilities of the algorithm. In [4, 5], the authors stated that drama represents the integration of resources needed to develop drama and the implementation of localization and characteristic strategy of TV drama, while in [6], the authors explained how to effectively obtain drama resources in the network platform has become a significant problem to be solved. Many authors combined drama with today's technologies, that is, big data, wireless sensor technology, and artificial intelligence, to facilitate human from low cost, high speed, and low data consumption [28].

3. Proposed Work

In this section, we discuss our proposed network platform for drama resource along with acquisition of drama resources on the network platform based on wireless sensor technology; after that, we will discuss Quantum Genetic Algorithm based on our proposed scheme, and at the end of this section, we will combine drama resources with the fuzzy attribute feature detection method for realization of the our proposed system [29].

3.1. Network Platform Drama Resource Collection Platform. In the process of drama resource mining on the network platform, drama resources are generally not indexed by search engines, and these high-quality drama resources cannot be directly obtained through search engines. This needs some mechanisms that enable search engines to obtain drama resources with high efficiency, thanks to drama resource mining, which has the ability to improve the coverage rate of drama resources by search engines [21]. Keeping in view of this, we have planned a drama resource collection platform that mainly includes page processing module, drama resource query interface recognition and classification module, and link construction and validity verification module. Furthermore, effective links and corresponding page contents in our proposed drama resources are found and used as resources to be searched by search engines. The drama resource collection platform mainly includes the following modules: page download and processing module, drama resource query interface recognition and classification module, link construction and validity verification module, and storage module. The overall schematic diagram is shown in Figure 1.

The following is a brief introduction to the functions implemented by each module in the drama resource collection platform of the network platform:

(1) Page download and processing module: the main task of this module is to obtain the page source code which enables page downloading and processing. Since the page source code contains a lot of impurity information, the page source code needs to be cleaned up and converted into a DOM tree for easy operation; otherwise, it will affect the efficiency of resource collection and processing [1].

(2) Drama resource query interface recognition and classification module: this is another important module of our proposed scheme. This module is connected with the users who seek drama resource. The main task of this module is to recognize the desired query and classify the drama resource query interface by field, removing irrelevant query interface.

(3) Link construction and validity verification module: this is another most important module of our proposed scheme, which is connected with drama resource query interface recognition and classification module. In this module, URL links are constructed mainly by querying keywords, querying drama resource keywords, at the same time, using more links to find more URL links, and verifying the validity of all URL links validity, filtering out the query results that cannot be obtained.

(4) Storage module: this is the last module of our proposed scheme that enable our system to save the verified valid URL link and its corresponding page information, so as to obtain the network platform drama resource collection result.

3.2. Acquisition of Drama Resources on the Network Platform Based on Wireless Sensor Technology. Because of the diversity of drama resources, it is not comprehensive to obtain the results of drama resources only through the network platform, so it is necessary to further collect the drama resources. As a new technology concept, the rapid development of wireless sensor technology has made it widely used in many fields such as consumer electronics, crop monitoring, livestock health monitoring, and medical services. In various factory environments, wireless local area network technology has been widely used as a communication information transmission tool between workers [30]. At the same time, radio frequency identification technology (RFID) as an electronic tag is also used in public transportation systems and personnel identification systems in the service industry widely used. The RFID system is explained in Figure 2.

The RFID tags in our proposed system are talented to identify every drama resource independently. This RFID is accomplished by analysis of numerous tags concurrently and instantly and can manage with strict and dirty environments. Furthermore, the RFID tags can also hold larger quantities of data, and data on tags can be read or simplified deprived of line of sight. These tag items are reusable and can also be automatically tracked out without the input of worker which eliminates the human errors, and they are not spoiled as simply like barcodes.

Our proposed scheme uses RFID technology in wireless sensor technology as a solution to collect drama resources on the network platform [31]. Among them, the wireless communication chip of the radio frequency transceiver module is TRY6831. In order to meet the low power consumption requirements of the node, the SQ series embedded microcontroller produced by TI is used as the main control module of the node.

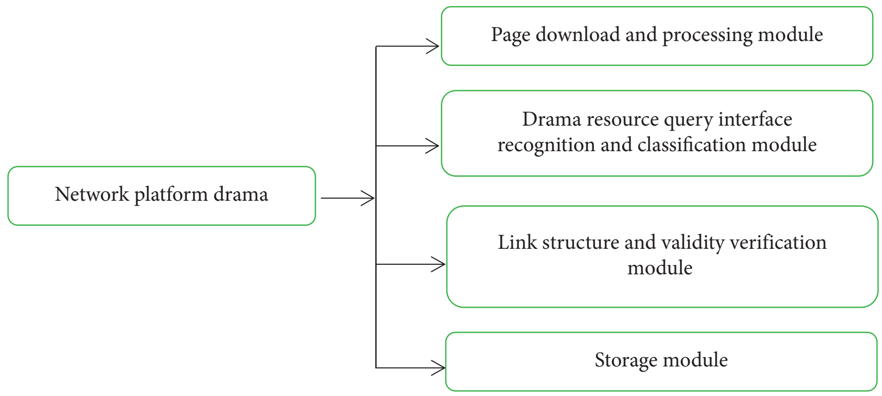

Figure 1: Schematic diagram of network platform drama resource collection platform.

Figure 2: RFID system and its components.

The TXD end of the embedded single-chip microcomputer is connected to the RXD end of the sensor, the RXD end of the single-chip microcomputer is connected to the TXD end of the sensor, the power ground is the GND end, and the VCC end is connected to a 5 V power supply. The data resources are transferred to the embedded single-chip microcomputer to obtain the resource collection results. The circuit diagram of the network platform drama resource acquisition sensor is shown in Figure 3.

The resource collection nodes in Figure 3 are connected by a TRY6831 wireless communication chip. The chip has a transmission rate of 320 kb/s and a transmission distance of 11.2 m. It has the characteristics of high performance, low power consumption, and low cost.

The wireless sensor network protocol can be logically divided into two types: voice-oriented and data-oriented. In many wireless networks based on data transmission, small, low-cost, low-complexity wireless sensor networks are widely used. The wireless sensor network protocol essentially implements the connection of the entire protocol through the interface between the user and the protocol entity. For a specific layer user, it can call some services provided by the current layer protocol entity through service primitives. In the process, the current layer protocol entity will also call service primitives to return some status information to the user [32, 33]. The IEEE 802.15.4 and Zigbee alliance are committed to making low energy consumption, low-rate transmission, and low cost as important goals. The IEEE 802.15.4 standard and the Zigbee protocol specification have standardized the functions that should be implemented at each layer in the form of service primitives. The work of implementing the protocol is to implement the various primitives in the standard, aiming to provide a unified standard for the long-distance and low-speed interconnection between individuals and devices. IEEE 802.15.4 defines 13 PHY layer service primitives and 35 MAC layer service primitives.

(1) Physical layer (PHY): this indicates the physical layer which is mainly responsible for data modulation and demodulation, sending and receiving, directly operating the physical transmission medium (radio frequency) downwards, and providing services for the MAC layer upwards.

(2) Media access control (MAC): this layer is also called Data Link Layer, which is responsible for single-hop data communication between adjacent devices. It is also responsible for establishing synchronization with the network, supporting association and disassociation, and MAC security; it can provide a reliable connection between two devices.

(3) Network (NWK): this is the 3rd layer of our proposed Wireless Sensor Network Protocol Stack (Figure 4), which determines the mechanism used when devices are connected and disconnected from the network. This layer performs route discovery and route maintenance between devices. This layer also completes the discovery of neighboring devices within one-hop range and storage of related information, creates a new network along with it, and assigns network addresses for new networked devices [17].

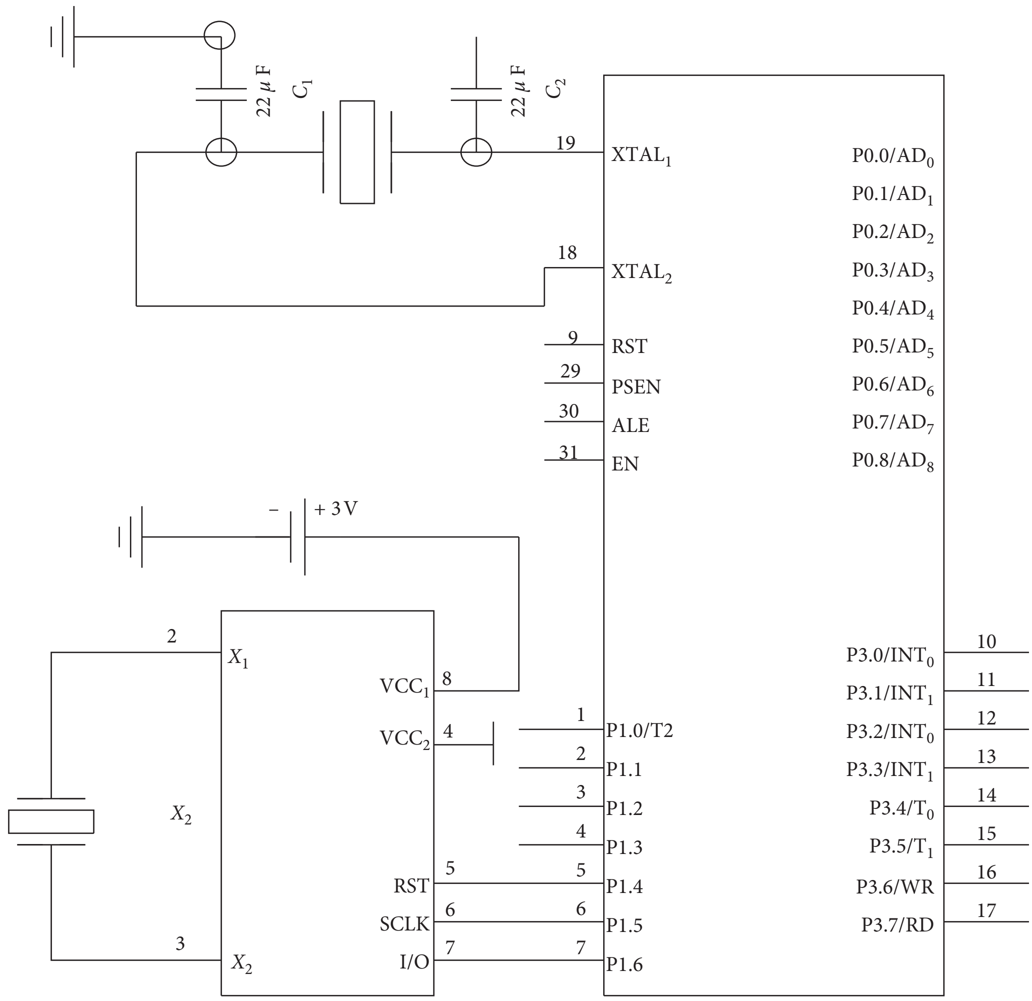

FIGURE 3: Network platform drama resource acquisition sensor circuit diagram.

(4) Application sublayer (APS): this is the 4th layer of the proposed Wireless Sensor Network Protocol Stack. This layer provides all endpoints services and connects to the device through the network layer and the security service provider layer and also provides services for data transmission, security, and binding. Therefore, it can adapt to different but compatible devices.

(5) Application layer (APL): this is the top most layer connected with the application software or user. This layer can configure and access network layer parameters through Zigbee Device Objects (ZDO) and provides them to application sublayer.

We have explained acquisition of drama resources and established wireless sensor network protocol stack; now, an algorithm is needed to classify the provided database and to mine the drama resources. In the next section, we will explain Quantum Genera Algorithm to achieve the desired goals.

3.3. Proposed Quantum Generic Algorithm for the Classification of Drama Resource. In this section, we discuss the classification algorithm (Quantum Generic Algorithm) for our proposed drama resource platform. As we know, classification is a form of data analysis that can be used to extract and describe important data categories. This analysis helps to understand the data better and comprehensively. There are many classification methods, such as the establishment of decision tree classifiers, naive Bayes classifiers, Bayesian belief networks, rule-based classifiers, and quantum genetic algorithms [34]. In the Quantum Genetic Algorithm, individuals are coded with the probability amplitude of qubits, the phase rotation of qubits based on quantum gates is used to realize individual evolution, and quantum NOT gates are used to realize individual mutation to increase the diversity of the population.

A qubit is a two-state quantum system that serves as an information storage unit. It is a unit vector defined in a two-dimensional complex vector space [35]. This space consists of a pair of specific orthonormal basis $\{|0\rangle, |1\rangle\}$. Therefore, it can be in the superposition of two quantum states at the same time. It is defined as $|\beta\rangle = \varphi|0\rangle + \lambda|1\rangle$, where φ and λ are two complex numbers, representing the probability amplitude of the corresponding state, and satisfying the normalization condition $|\varphi| + |\lambda| = 1$. A system containing n qubits can represent 2^n states at the same time. When observing, the system will form a certain state.

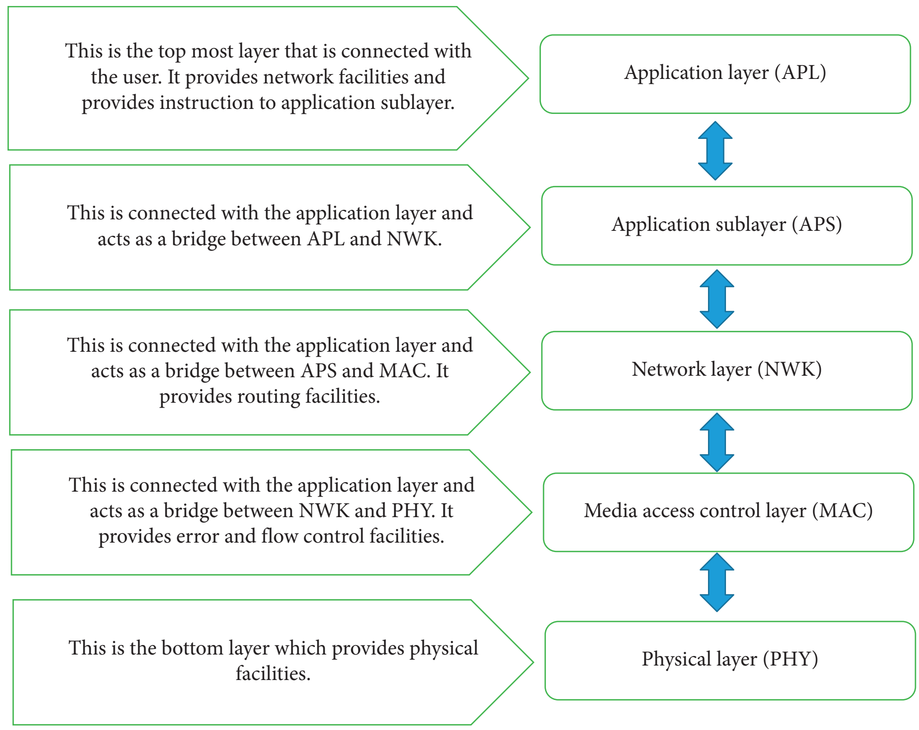

FIGURE 4: Wireless sensor network protocol stack.

There are many ways to encode chromosomes in traditional genetic algorithms: binary, decimal, symbolic encoding, etc. In the quantum genetic algorithm, an encoding method based on qubits is used. A qubit can be defined as

$$\begin{bmatrix} \varphi \\ \lambda \end{bmatrix}, \tag{1}$$

by its probability amplitude, and similarly, k qubits can be defined as

$$\begin{bmatrix} \varphi_1 & \varphi_2 & \varphi_k \\ \lambda_1 & \lambda_2 & \lambda_k \end{bmatrix}. \tag{2}$$

Among them, $|\varphi_i| + |\lambda_i| = 1$, $i = 1, 2, \ldots, k$. This coding method makes the population have better diversity, and as $|\lambda|$ and $|\lambda|$ tend to 0 or 1, the chromosome converges to a single state.

Our proposed Quantum Genetic Algorithm is based on the expression of quantum state vectors. It applies the probability amplitude representation of qubits to chromosome encoding, so that one chromosome can express the superposition of multiple state vectors, and uses quantum revolving gates to achieve chromosome update operations, the introduction of quantum mutation to overcome the premature phenomenon, and finally achieve the goal of optimization solution [36].

In the proposed Quantum Genetic Algorithm, the probability amplitude of a qubit can be expressed as $\begin{bmatrix} \varphi \\ \lambda \end{bmatrix}$; then, the probability amplitude of k qubits can be expressed by the following equation:

$$\alpha_k = \begin{bmatrix} \varphi_1 | \varphi_2 & \ldots & \varphi_k \\ \lambda_1 | \lambda_2 & \ldots & \lambda_k \end{bmatrix}. \tag{3}$$

Among them, the probability amplitude satisfies the normalization conditions given in the following equation:

$$|\varphi_i| + |\lambda_i| = 1. \tag{4}$$

Here, $i = 1, 2, \ldots, k$. If there is a quantum system with 3-bit quanta and three pairs of probability amplitudes, it can be expressed by the following equation:

$$\begin{bmatrix} \dfrac{1}{\sqrt{\varphi}} & 1 & \dfrac{1}{2} \\ \\ \dfrac{1}{\sqrt{\varphi}} & 0 & \dfrac{\sqrt{\lambda}}{2} \end{bmatrix}. \tag{5}$$

Then, the state of the system can be described by the following equation:

$$\frac{1}{2\sqrt{\varphi}}|000\rangle + \frac{\sqrt{\varphi}}{2\sqrt{\lambda}}|001\rangle + \frac{1}{2\sqrt{\varphi}}|100\rangle + \frac{\sqrt{\varphi}}{2\sqrt{\lambda}}|101\rangle. \tag{6}$$

Therefore, the probability of the system appearing in states $|000\rangle$, $|001\rangle$, $|001\rangle$, and $|101\rangle$ is 1/8, 3/8, 1/8, and 3/8, respectively. Therefore, the three-bit quantum system described by the above equation can contain 4 states of information at the same time.

For the above equation, one chromosome can describe 4 states [37]. But in traditional evolutionary algorithms, 4 chromosomes are needed to describe 4 states, namely, (000), (001), (100), and (101). Populations described based on quantum chromosomes also have diversity. When $|\lambda|$ and $|\lambda|$ tend to 0 or 1, the diversity will gradually disappear, and the quantum chromosome will converge to a certain state, which shows that the quantum chromosome has the ability to explore and develop at the same time.

Our proposed Quantum Genetic Algorithm is similar to the traditional Genetic Algorithm in that it is also a probabilistic search algorithm. Suppose a quantum population is given in the following equation:

$$W(t) = \left\{w_1^t, w_2^t, \ldots, w_n^t,\right\}. \tag{7}$$

Here, t represents the genetic algebra, while w_l^t represents the l chromosome of the t generation, and the definition of w_l^t is as shown in the following equation:

$$w_l^t = \begin{bmatrix} \varphi_1^t | \varphi_2^t & \ldots & \varphi_m^t \\ \lambda_1^t | \lambda_2^t & \ldots & \lambda_m^t \end{bmatrix}. \tag{8}$$

Here, m represents the qubit number, which is the length $L = 1, 2, \ldots, m$ of the chromosome. According to the above analysis, the process of our proposed platform drama resource classification algorithm based on quantum genetic algorithm is as follows.

3.4. Proposed Quantum Generic Algorithm. In this section, we present an effective quantum generic algorithm for our proposed drama resource mining.

```
Begin
  [Start Algorithm]
t = 0;
  Initialize population W(t)
[Initialization]
Observe the state of W(t) to generate a binary solution
R(t)
  [Generate binary solution]
Calculate fitness
  [Calculation of fitness]
Store the optimal solution
  [Store the solution]
While (meeting the loop condition) [loop start]
  Begin
  t = t + 1
Observe the state of W(t) and generate a binary solution
R(t)
 [Generate binary solution]
Calculate fitness function
 [Calculate fitness]
Calculate the quantum gate update W(t)
 [Calculate Quantum Gate]
Store the optimal solution
 [Store solution]
End
```

3.5. Explanation of the Proposed Quantum Generic Algorithm. In this section, we explain the procedure of proposed Quantum Generic Algorithm. Here, the algorithm first initializes the population. When the population is initialized, all the probability amplitudes of 2^m of all chromosomes are initialized to $1/\sqrt{2}$, which means that when the current number $t = 0$, the linear superposition probability of each chromosome in all possible states is the same, which can be seen in the following equation:

$$\left|\mu_p^0\right\rangle = \sum_{c=1}^{2^n} \frac{1}{\sqrt{2^n}} |h_c. \tag{9}$$

Among them, h_c represents the cth state, which is described by the binary string $(y_1, y_2, \ldots, y_g)$, $g = 1, 2, \ldots, m$.

Secondly, in the calculation process, the binary solution is set as follows:$K(t)$ is generated by observing the state of the population $W(t-1)$. Each solution is a binary string of length L, and its value is determined by the observation probability of the corresponding qubit. Then, calculate the fitness of each solution according to the obtained value to find the optimal solution.

In addition, in order to obtain a better chromosome, the binary solution

$$K(t) \tag{10}$$

is compared with the current optimal solution, and the population,

$$W(t-1), \tag{11}$$

is updated with an appropriate quantum gate $R(t)$. Specific quantum gates can be designed according to specific problems. The commonly used quantum revolving gate is shown in the following equation:

$$R(t) = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix}. \tag{12}$$

Here, θ represents the angle of rotation.

Finally, the optimal solution of the binary solution set $K(t)$ is selected. If the optimal solution is better than the optimal solution of the current platform drama resource classification, the optimal solution is used to replace the optimal solution of the current platform drama resource classification to realize the platform drama resource optimize classification.

3.6. Realization of the Mining of Drama Resources on the Network Platform. In this section, we discuss mining of proposed drama resource on the network platform. By mining the semantic association feature quantity of frequent patterns of platform drama resources, combined with the fuzzy attribute feature detection method, the network platform drama resources mining is realized. Combined with the autocorrelation feature detection method, the statistical analysis of frequent pattern mining of platform drama resources is carried out, and the fuzzy correlation fusion model of frequent pattern mining of platform drama resources is established; the feature segmentation model of platform drama resource frequent pattern data is established [37], which is expressed by the following equation:

$$\begin{bmatrix} r_1 \\ r_2 \\ r_3 \\ \cdots \\ r_N \end{bmatrix} = \begin{bmatrix} r_{11}, & r_{12}, & r_{13}, & \cdots & r_{1N} \\ r_{21}, & r_{22}, & r_{23}, & \cdots & r_{2N} \\ r_{31}, & r_{32}, & r_{33}, & \cdots & r_{3N}, \\ & & \cdots & & \\ r_{N1}, & r_{N2}, & r_{N3}, & \cdots & r_{NM} \end{bmatrix} \times \begin{bmatrix} e_{i1} \\ e_{i2} \\ e_{i3} \\ \cdots \\ e_{NM} \end{bmatrix}. \tag{13}$$

Among them, r_{NM} represents the global weighted value of the frequent pattern data mining of platform drama resources at the Nth point, constructs the STARMA (1, 1) statistical analysis model of the frequent pattern data of graph data, and performs optimization control of the frequent pattern data mining of platform drama resources, expressed by the following equation:

$$\rho_k = \left[\rho + (1-\rho)\frac{\eta}{W_k}\right]^N. \tag{14}$$

Here, ρ represents the fuzzy rule feature quantity of the frequent pattern mining of the platform drama resource data, using the statistical information analysis method, establish the platform drama resource frequent pattern data mining associated feature distribution set, and express it by the following equation:

$$S_h = \frac{C_{\mathrm{ih}} + C_{\mathrm{oh}} - C_{\mathrm{io}}}{C_{\mathrm{io}}} \times \rho_k. \tag{15}$$

Here, C_{ih} represents the input space, C_{oh} represents the output space, and C_{io} represents the high-dimensional feature space. The calculation equations of the above three parameters are

$$\begin{aligned} C_{\mathrm{ih}} &= \frac{|C|}{|s|}, \\ C_{\mathrm{oh}} &= \frac{\mathrm{NB}}{|C|}, \\ C_{\mathrm{io}} &= \frac{\mathrm{NS}}{|S|}. \end{aligned} \tag{16}$$

Here, NB represents the closed frequent item set and NS represents the semantic segmentation domain.

Finally, the big data fusion method is used to perform pattern matching and information fusion clustering of frequent pattern mining of platform drama resources. At feature point a, the frequent pattern distribution set of platform drama resources is expressed as in the following equation:

$$A = \{a_1, a_2, .., a_v\}^f. \tag{17}$$

Here, v represents the number of frequent pattern data of platform drama resources, and f represents the weighting coefficient of frequent pattern mining of platform drama resources. Through the semantic dynamic feature segmentation method, the standard error coefficient of platform drama resource mining is obtained as in the following equation:

$$X = x_i + A\left(x_{i\,\max} - x_{i\,\min}\right). \tag{18}$$

Here, $x_{i\,\max}$ represents the fuzzy constraint feature quantity of platform drama resource frequent pattern mining and optimization. Establish a storage module and an information query module for frequent pattern mining of platform drama resources, and establish a feature extraction and classification model for frequent pattern mining of platform drama resources to obtain the final mining output results given in the following equation:

$$x_k = \sum_{i=1}^{N} w_i X^{k-1}. \tag{19}$$

The result calculated by equation (19) is the output result of platform drama resource mining, thus completing the design of the network platform drama resource mining method based on wireless sensor technology.

4. Simulation and Experimental Work

In order to verify the effectiveness and comprehensiveness of the network platform drama resource mining method based on wireless sensor technology, simulation experiments are performed. Compared to the method used in [7, 8], we have used mining time, the comprehensiveness of the mining results, and the accuracy of the mining results as the experimental indicators.

4.1. Experimental Environment. We have carried out our experimental work for the proposed scheme, by using Linux Ubuntu 10.10 64-bit software, Intel Xeon E5606 4G memory 1T hard disk, VIM editor and CodeBlock development tools, and C++ as programming language.

4.2. Experimental Data. The experimental data comes from a local drama database, which includes three subdatabases: an index database, a data database, and a video database. The data sublibrary records information such as drama types, repertoires, characters, documents, pictures, and the video sublibrary records audio-visual data of the play. The index sublibrary provides indexes for the data sublibrary and the video sublibrary. Figure 5 shows the structure diagram of the database.

4.3. Experimental Results. In this section, first, we discuss the resource mining time, comprehensiveness of resource mining results, and accuracy of mining results. During our experimental work, we compare our scheme with the work of [7, 8].

4.3.1. Resource Mining Time. Comparing the mining time of different methods, the results are shown in Figure 5. In this figure, we have compared our proposed design with the

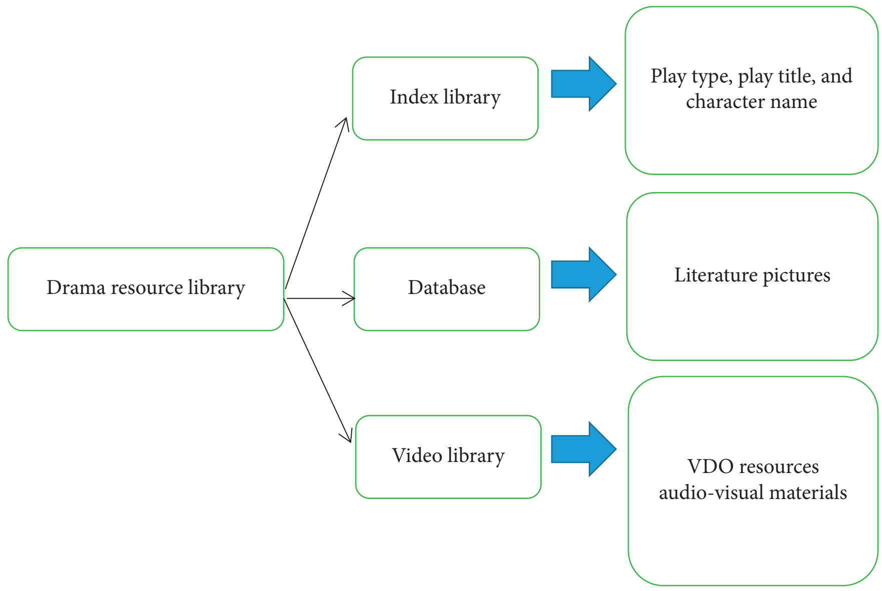

Figure 5: Structure diagram of drama database.

work of [7, 8]. The rest will be explained in the coming section.

Analyzing Figure 6, it can be seen that the mining time consumed when mining resources using the method in this paper is significantly lower than that in reference [7] method and reference [8] method. The mining time of the method in this paper shows a continuous downward trend. When the number of the iterations is less than 6 times, the excavation time decreases significantly, and then the change trend of excavation time slows down, and the lowest value of excavation time is only 0.8 s. By comparison, it can be seen that the mining time of this method is shorter, which shows that the resource mining efficiency of this method is higher.

4.3.2. Comprehensiveness of Resource Mining Results. Comparing the comprehensiveness of the resource mining results of different methods, the results are shown in Table 1.

Analysis of the data in Table 1 shows that the method in this paper can mine up to 19 types of drama resources, and the lowest is 13 types, while reference [7] method and reference [8] method can mine fewer types of resources, far below the method of this research work. Among them, reference [7] method can only mine 9 drama resources at most, and reference [8] method can only mine 8 drama resources at most. Through comparison, it can be seen that the resource types obtained by mining method in this paper are more comprehensive, which shows that its application effect is better.

4.3.3. Accuracy of Mining Results. Comparing the accuracy of the mining results of different methods, the results are shown in Figure 6. In order to get the accurate results of mining, we have compared our proposed model with the work of [7, 8]. The rest will be explained in the coming section.

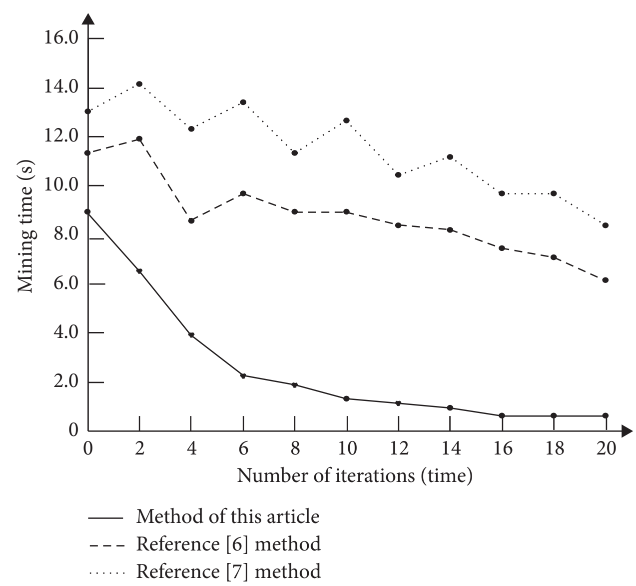

Figure 6: Comparison results of mining time.

According to Figure 7, the resource mining accuracy rate of this method is significantly higher than that of the traditional method. When the number of iterations is 5, the mining accuracy rate of this method reaches 60%, and the mining accuracy rate of the method in reference [7] method is 47%; the mining accuracy rate of reference [8] method is 43%. When the number of iterations is 14 times, the mining accuracy of the method in this paper reaches 82%, the mining accuracy of the method in [7] is 56%, and the mining accuracy of the method in [8] is 62%. Through comparison, it can be seen that the mining results of the method in this paper are more accurate, indicating that the mining results are more reliable.

Comprehensive analysis of the above experimental results shows that the minimum mining time of this method is only 0.8 s, which can mine up to 19 types of drama resources, and the

Table 1: Comprehensive comparison of resource mining results of different methods.

Number of iterations (time)	Resource type mining quality		
	[7] method	[8] method	Method of this paper
2	7	7	15
4	9	6	13
6	8	8	14
8	7	6	15
10	8	6	16
12	6	5	19
14	7	7	15
16	8	8	16

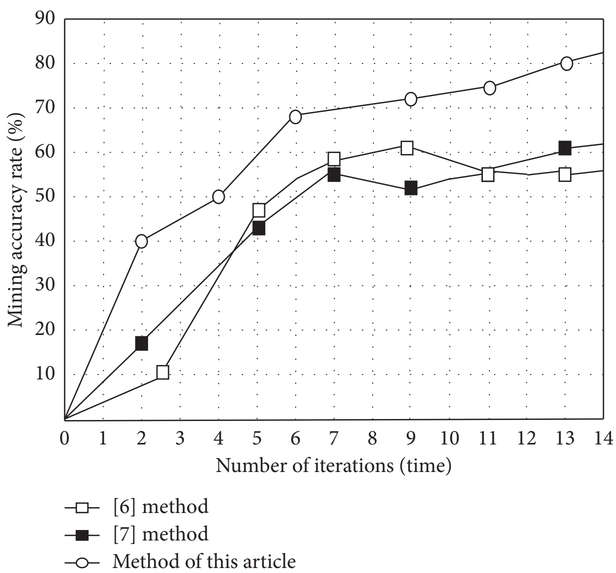

Figure 7: Comparison of accuracy of mining results of different methods.

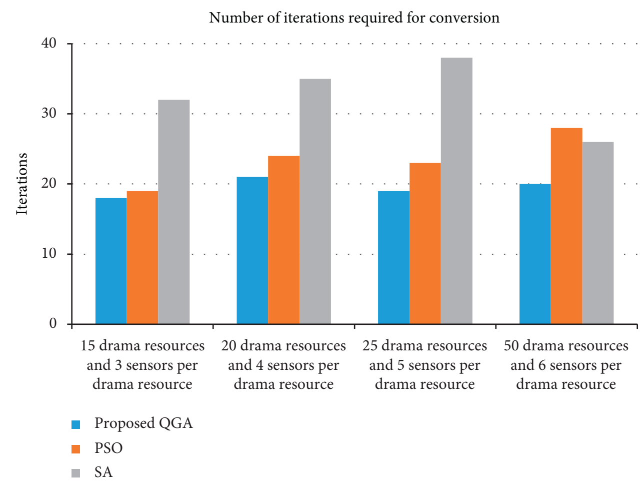

Figure 8: Conversion comparison of SA, PSO, and proposed QGA.

mining accuracy rate reaches 82%. This method has obvious advantages in mining time, mining comprehensiveness, and mining accuracy, which shows that the mining results of this method are more reliable and the mining efficiency is higher.

The network efficiency of the proposed QGA technique in target allocation is examined, and QGA provides a comparison with the Particle Swarm Optimization (PSO) and Simulated Annealing (SA) algorithms in wireless sensor technology for target allocation. Then, the efficiency of QGA is compared with different amounts of target points and number of sensors. The entire testing procedure is carried out on a computer using the same hardware and software.

Figure 8 shows how much iteration is necessary for SA, PSO, and our proposed QG algorithm to reach convergence under various simulated conditions. The range variation percentage judgment approach is used to determine convergence. The variation limit specified in this experiment is 1% to 2%; that is, the algorithm can be regarded convergent if the rise percentage of network efficiency achieved by the algorithm is between 1% and 2%. As a result, our suggested Quantum Generic Algorithm appears to have a better convergence performance.

5. Conclusion

In conclusion, this paper puts forward an efficient Quantum Generic Algorithm (QGA) for drama resource mining based on wireless sensing technology. From the perspective of drama resource, this paper makes a mathematical model and then uses the proposed algorithm to solve the mathematical model. The results show that it is effective in solving the problem of resource mining time, comprehensiveness of mining results, and accuracy of the mining results into the sensor target allocation problem. The results prove the effectiveness of the QGA-based drama resource in optimizing network efficiency of the wireless sensing technology. By applying QGA, a more efficient drama resource mining scheme can be obtained when drama resource mining is carried out. Not only does the scheme obtain the maximum monitoring effect of the drama resource, but also it saves mining time and produces accurate results. Through the suitable deployment of sensors, limited resources can be used as much as possible. Future research should carefully consider other methods that can further improve the network efficiency of drama resource mining, such as combining routing optimization algorithms and clustering and machine learning techniques.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that he has no conflicts of interest regarding the publication of this paper.

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Research Article

Research and Application of the Interactive English Online Teaching System Based on the Internet of Things

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Nowadays, due to the pandemic and other problems, the establishment of physical classes is a big headache for both students and teachers, due to which the education system all over the world is shifted to the online system from the physical system. Advance technologies such as the Internet of Things (IoT) are playing a significant part in various sectors of life such as health, business, and education. In order to effectively improve the effect of online English teaching, this study designed an interactive online English teaching system based on the IoT technology. This study proposes three topological structures for the establishment of the proposed IoT-based online English teaching system. Based on the analysis of the three topological structures of the IoT, this study chooses to design each submodule of the front and back of the system in the network IoT environment to realize the daily operation and various functions of the system and to realize the interactive design of both of the teacher and student side. Based on this approach, an online English teaching system is designed, and the teaching quality based on this system is evaluated with the help of an algorithm known as grey relational analysis algorithm. The experimental results show that, after the application of this system, students have access to the teaching materials and content in a short period of time; and the English test scores were improved and were significantly higher as compared to the traditional teaching system. In addition, at the same time, the internal consistency reliability of the proposed system is very high which fully demonstrates the effectiveness of the proposed system.

1. Introduction

The 21st century is an era of technology, economy, and educational knowledge. The rapid increase and development in knowledge have brought enormous convenience in every field of life.

Among the new technologies, educational technology not only needs to change traditional approaches but also hastens the transformation of people's ideas and educational thoughts. Traditional learning strategies are currently being impacted greatly by the enormous amount of information available. The conventional teaching methods are far from meeting the requirements of the modern century, given the rapid increase in awareness and rapid technological growth.

The teachers and other supporting staff give full attention and value to each student by helping them in their studies and try to assist them using their full potential, for a long time. The use of teaching machines and other supporting tools can improve the personalized teaching and have a direct impact on the performance of the students. Classroom teaching utilities have always been optimized for the needs of education, from the basic teaching machines to the implementation and deployment of the new intelligent teaching systems and devices. The combination of IoT and CAD-based teaching systems has made a novel field of research, which is known as smart teaching system [1, 2]. The student's learning burden will help teachers to be more efficient in the classroom, allowing them to conduct empirical research, intelligent judgement, and a purposeful, accurate, systematic, and targeted instruction, which eventually enhances students' academic performance and overall education quality.

The forms of multimedia teaching are becoming more and more diversified and are developing towards the mode of independent research and development. At the same time, development in the field of information technology (IT) also promotes new and advanced educational models, and education modernization had become an important resource to improve the quality of education [3]. Among the educational models, teaching system is one of the representative products of education modernization. With the popularization of computer and network technology, the methodology of the teaching system is enhanced, and the scope of its applications has been extended, which results in the development of an interactive teaching system. By giving full attention to the subjective initiative of teachers and students in the teaching process, the teaching system promotes the communication between teachers and students, pays attention to the participation and enthusiasm of students, and effectively integrates the education and learning stages [4, 5].

With the progress of science and technology in the modern era, the online teaching system has made a major breakthrough. Yi et al. [6] designed the mobile terminal interactive teaching system based on augmented reality technology. Their system aims at cultivating the course map and introduces the augmented reality technology into the course teaching process so that the learners can actively participate in the setting of key parameters of the system. At the same time, the system can also present the rendering results to the learners in real time, achieving the effect of immediate feedback and interactive communication. Luan [7] designed a 3D interactive teaching system based on the contradiction space. Based on the analysis of the best demonstration mode of the contradiction space, the system combined with Unity3D virtual reality technology to build a digital 3D interactive teaching system of the contradiction space, so as to solve the problem of poor teaching demonstration effect to the greatest extent. However, in the practical application, it was found that the ideal degree of teaching results of the aforementioned two teaching systems was relatively low.

With the development of economic globalization, countries around the world have formed a community of interests, and the challenges of global issues require all countries to work together to deal with them. In this process, English, as the global language, became a bridge of communication between countries. Online English teaching system breaks the traditional teaching mode limited by time and place. Therefore, with the rapid development of network and multimedia technology, teachers should make full use of the internet technology and multimedia technology to achieve efficient online teaching, so as to improve the diversity, information, knowledge, and fun of the English teaching process and promote the improvement of English teaching quality [8, 9].

The Internet of Things (IoT) is a network that collects information in real time through a variety of sensing devices, radio frequency identification, positioning, scanning, and other technologies, realizes a ubiquitous connection between things and things and between things and people through various possible network access, and effectively manages the collected information [10, 11]. At present, IoT technology has been able to effectively realize the collection, storage, processing, interconnection, and application of data information. The main contributions of this paper are as follows:

- In view of the shortcomings of the traditional system, this study applies the IoT technology to the information collection process at different ends of the online education system and designs a new interactive English online teaching system by using the IoT technology
- The time of accessing the online English teaching contents is significantly decreased, which reduces the delay problem
- The test scores of the randomly selected students are increased and left the other teaching systems far behind
- The critical factors that influence the learning process of students using the online English teaching environment were identified

The remaining paper is structured as follows: Section 2 demonstrates building an IoT environment, Section 3 represents the design of the proposed interactive English online teaching system, and Section 4 notifies simulation results and experimental analysis. Finally, we conclude our research work in Section 5.

2. Building an IoT Environment

The IoT is a network based on information carriers such as the internet and traditional telecommunication networks, which enables all ordinary objects that can perform independent functions to achieve interconnection. According to the positions of each measuring point in the IoT, the structure of IoT can be divided into three topological structures: star, tree, and network topology. The specific structure of the mentioned topologies is shown in Figures 1–3.

In all of the three figures, node 1 represents the coordinator, node 2 demonstrates the router, and node 3 shows the terminal device. Figure 1 illustrates the star topological structure. In Figure 1, the star topological structure has a single-hop network composed of a coordinator and multiple terminal devices. There is only communication between the coordinator and each terminal device, and the communication between each terminal device is forwarded by the coordinator.

Figure 2 represents a tree topological structure of the IoT network. The tree structure is composed of a coordinator and a number of router and terminal devices. In addition to point-to-point direct communication with parent or child nodes, the device can only complete message transmission through tree routing [12, 13].

Figure 3 demonstrates the IoT network topological structure diagram. The network IoT structure consists of one coordinator and multiple router and terminal devices. The main difference is that the mesh structure allows all nodes with the routing function to be connected directly, and the routing table in the router is used to realize the network routing of the message, which reduces the message delay at the cost of more storage space and enhances the reliability.

This study mainly focuses on an interactive English online teaching system based on the network Internet of Things environment.

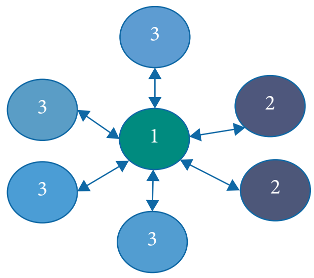

Figure 1: Internet of Things star topology structure diagram.

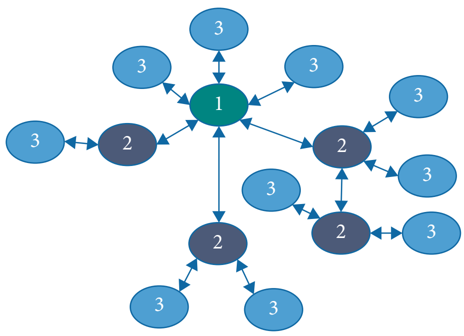

Figure 2: Internet of Things tree topology structure diagram.

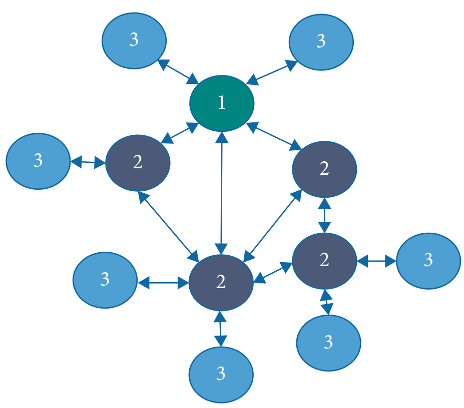

Figure 3: Internet of Things network topology structure diagram.

3. Design of the Interactive Online English Teaching System

The interactive online English teaching system based on the IoT technology is implemented in the network IoT environment by Android and Web dual mode. Among them, the main function of the online interaction part is to provide teachers and students with teaching interaction and English teaching resource-sharing channels. The overall system architecture is shown in Figure 4.

3.1. Designing and Deployment of System Hardware. This section represents the design and deployment of hardware for the proposed interactive online English teaching system. In order to fully reflect the design advantages of the interactive online English teaching system, this study focuses on a comprehensive analysis of teachers' and students' demands for the teaching system. The basic principles which need to be followed in the system design process are represented in a summarized form as follows:

(a) Availability: the online English teaching system mainly takes the demand of both teachers and students as the ultimate design goal of the proposed system. It will be convenient for the users of the system to join the system where they can find a large number of experts in the relevant field, with a greater experience. The real-time analysis and service demand of teachers and students provide the corresponding practical functions at a platform which is used by both students and teachers.

(b) Safety and reliability: a practical teaching system must be safe and reliable [14, 15]. To do so, this paper combines advanced software and hardware in the design process to obtain the best design scheme and ensures the safety and reliability of the proposed teaching system.

(c) Maintainability: indeed, maintenance is an important factor of a system that has a great impact on the performance of a system. The proposed system operates in real time and is maintainable in terms of both hardware and software.

(d) Expandability: the design of the system is mainly not only convenient for the follow-up business development and expansion but also to facilitate the design and maintenance of various aspects of the system.

3.1.1. System Foreground Design. The front desk of the system is divided into five parts, i.e., web page module, teaching resource module, teaching video module, message and discussion module, and user management module. All of the mentioned modules are briefly described in the following:

(a) Web module: this module is mainly used to display the main functions and contents of the teaching system which include the user login, supporting materials, website use, and other related operations.

(b) Teaching resource module: this module is used to facilitate the users to query all the teaching resources contained in the system, including syllabus, teaching plan, electronic courseware, English grammar knowledge, simulation tests, and other contents.

(c) Teaching video module: this module automatically displays all the teaching videos in the database in different terminals with greater detail. Users can watch the corresponding teaching videos after randomly clicking on an English teaching video title. Furthermore, the module is connected with the teaching resource database, which can realize the real-time update of the teaching video.

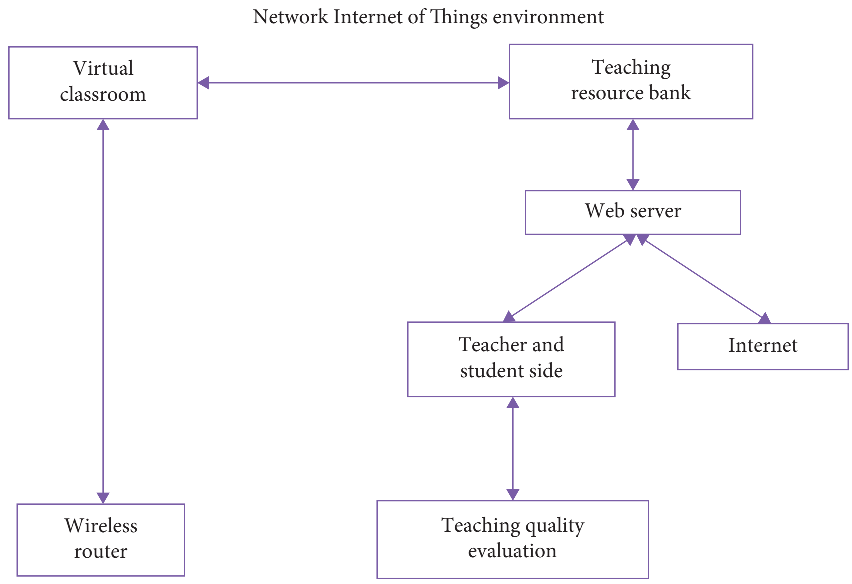

Figure 4: Overall architecture of the proposed system.

(d) Message and discussion module: this is another important module that plays an important role to enhance the quality and flow of communication among the students and corresponding teachers in conveying their messages. The students ask questions which will be transferred to the teachers in real time; after receiving the student message, the teachers will respond to the questions immediately, and hence, the learning process will be improved.

At the same time, in this module, students can complete information exchange, share learning resources with others, and start a group discussion on a certain topic. When the user clicks on the online BBS son module, a window is opened which shows all the information regarding the previous posts in the database. When a student clicks on the "remarks" option, it displays the corresponding presentation box, the students and other users need to be in the input text box in order to input their remarks, and after doing so, they need to click the "Finish" button which will close the remarks page.

(e) User management module: in this module, users can carry out information registration, login, personal information modification, course schedule selection, and other operations, which is also the basis of the whole teaching system.

3.1.2. System Background Design. The background of the proposed interactive online English teaching system is divided into three main parts which include the main interface module, teaching resource management module, and background management module. All of the three mentioned modules are described briefly as follows:

(a) Main interface module: this module uses the TreeView control to display all the functions of the background. The system administrator can enter the corresponding interface of each function by clicking the name of different functions.

(b) Teaching resource management and storage module: in this module, the window administrator can update, delete, and modify the teaching resources in the teaching system website, so as to ensure that the learning resources in the system are more real time and accurate.

(c) Background management module: using the window structure of this module, the administrator can modify and delete the users in the system. At the same time, in this module, the system administrator can also accomplish system maintenance, resource update, and other operations.

3.1.3. Interactive Module Design. In order to fully meet the business needs of the proposed interactive online English teaching system, teachers can interact with the students through the server side, such as checking students' attendance, generating the QR code, pushing relevant test questions of the course, and monitoring the learning status of the students. The composition of the teacher-side interaction module is shown in Figure 5.

This interactive module is mainly used for online interaction between students and teachers, which consists of three functional modules: scanning QR code, classroom interaction, and offline login. Students scan the QR code on the server and sign in, receive the instant message sent by the teacher, and can also reply to the teacher's message. If there is no teacher intranet, offline login is performed to view and review the history of messages pushed by the teacher. Through the online learning interface, students can connect to the external network for independent learning operation. The composition of the interactive module on the student side is shown in Figure 6.

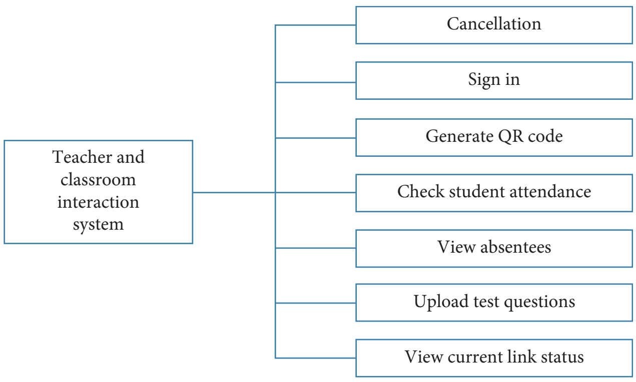

Figure 5: Schematic diagram of the teacher-side interaction module.

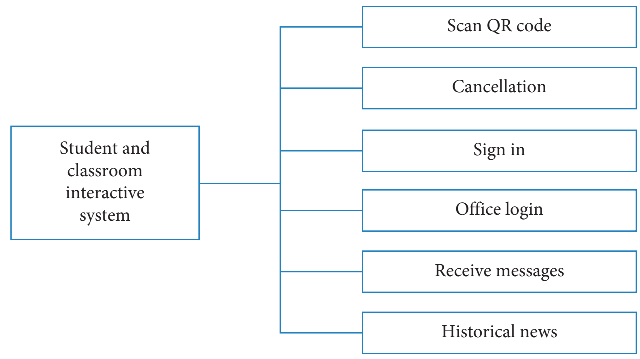

Figure 6: Schematic diagram of the interaction module on the student side.

3.2. System Software Environment Design

3.2.1. Design of the Online English Teaching Process. The teaching process design of the interactive English online teaching system based on the Internet of Things technology is as follows:

(a) Set reasonable teaching objectives:

$$Z_t^f = \begin{bmatrix} z_1^1 & z_1^2 & \cdots & z_1^f \\ z_2^1 & z_2^2 & \cdots & z_2^f \\ \vdots & \vdots & \ddots & \vdots \\ z_t^1 & z_t^2 & \cdots & z_t^f \end{bmatrix}, \tag{1}$$

where Z_t^f represents the teaching objective matrix, t describes the teaching progress, which is reflected by time, and f is the student's grade. As the design of teaching objectives and contents is gradual, their design mainly focuses on the following aspects.

Teaching objectives should have a sense of hierarchy, so as to improve students' English learning ability and effectively reflect the guiding role of online interactive English teaching. At the same time, attention should also be paid to the correlation between educational objectives so that the students can master the correlation between the two in the process of learning, that is,

$$Q_t^f = \begin{bmatrix} q_1^{f-\gamma} & q_1^{f-\gamma+1} & \cdots & q_1^{f-1} \\ q_2^{f-\gamma} & q_2^{f-\gamma+1} & \cdots & q_2^{f-1} \\ \vdots & \vdots & \ddots & \vdots \\ q_t^{f-\gamma} & q_t^{f-\gamma+1} & \cdots & q_t^{f-1} \end{bmatrix}. \tag{2}$$

Among them, Q_t^f represents the correlation matrix before and after educational goals; q denotes the learning factor; and γ notifies the student preference parameter. The design of teaching objectives pays more attention to the overall performance of the design of teaching objectives. In this process, the main focus is on the language knowledge, language skills, and emotional attitude that need to be integrated into the teaching objectives in order to enhance the students' learning ability. The following constraints should meet in the actual operations:

$$I_t^f = Q_t^f \times H = \begin{bmatrix} q_1^{f-\gamma} & q_1^{f-\gamma+1} & \cdots & q_1^{f-1} \\ q_2^{f-\gamma} & q_2^{f-\gamma+1} & \cdots & q_2^{f-1} \\ \vdots & \vdots & \ddots & \vdots \\ q_t^{f-\gamma} & q_t^{f-\gamma+1} & \cdots & q_t^{f-1} \end{bmatrix} \times \left(h^{f-\gamma}, h^{f-1-\gamma}, \ldots, h^{f-1}\right). \tag{3}$$

Here, H represents the grade sequence of students' achievement; h demonstrates the student achievement rating factor, and $h < 1$.

(b) Pay attention to teaching curriculum design:

The design of the English teaching course is the main component of the interactive English online teaching system. The design of the teaching process plays an important part in the achievement of the teaching objectives [16, 17]. Teaching process design is mainly based on teaching objectives and the basic elements of the teaching process. When teachers design the teaching process, they need to focus on the experience of the learning process by using different teaching strategies, teaching methods, and selection of teaching contents for the course organization and focus on the main characteristics of independent, cooperative, and inquiring learning methods.

3.2.2. Teaching System Quality Evaluation Module. In order to check the quality of the proposed system, this study also designs a teaching system quality evaluation module that uses the grey correlation analysis algorithm to evaluate the teaching quality and further improves the functions of the teaching system. The specific operation process is described as follows.

Step 1. Select the analysis sequence: in the first step, the reference sequence and comparison sequence are selected.

The former is the data sequence reflecting the behavior characteristics of the teaching system, and the latter is the data sequence composed of the influencing factors of the system behavior. The expressions of the reference sequence and the comparison sequence are given as follows:

$$\begin{aligned} A &= \{a(k) \mid k = 1, 2, \ldots, m\}, \\ C &= \{c_i(k) \mid k = 1, 2, \ldots, m\} \, (i = 1, 2, \ldots, n). \end{aligned} \tag{4}$$

Step 2. Dimensionless processing of variables: the dimensionless data of the system factor series may be inconsistent, which increases the difficulty of comparison and affects the accuracy results of the system. Therefore, the dimensionless processing strategy should be adopted in the process of grey relational degree analysis.

Step 3. Find the correlation coefficient: the following calculation formula is used to solve the correlation coefficient between the reference value $a(k)$ and the comparison value $c_i(k)$ [18, 19]:

$$\xi_i(k) = \frac{\min_i \min_k |a(k) - c_i(k)| + \delta \max_i \max_k |a(k) - c_i(k)|}{|a(k) - c_i(k)| + \rho \max_i \max_k |a(k) - c_i(k)|}. \tag{5}$$

If there is $|a(k) - c_i(k)| = \Delta_i(k)$, the above expression can be simplified to get the following expression:

$$\xi_i(k) = \frac{\min_i \min_k \Delta_i(k) + \delta \max_i \max_k \Delta_i(k)}{\Delta_i(k) + \delta \max_i \max_k \Delta_i(k)}. \tag{6}$$

In the above formulas, δ represents the resolution coefficient, and its value ranges in $\delta \in (0, \infty)$. The resolution increases with the decrease of the value, and the value range is reduced to $\delta \in (0, 1)$.

Step 4. Solution of correlation degree: the correlation coefficient is too dispersed, so the average of the correlation coefficient of all reference sequences and comparison sequences is g_i, which refers to the correlation degree between the sequences.

Step 5. Sorting of relational degree: the order of relational degree g_i is arranged from large to small. When $g_1 < g_2$, it means that the reference sequence is more similar to the comparison sequence. In other words, it indicates that the data sequence reflects the characteristics of the teaching system and is closer to the data sequence composed of the influencing factors of the system behavior. This process shows that the operation quality of the teaching system is better as compared to the other approaches.

4. Simulation Results and Experimental Analysis

This section represents the simulation results and experimental analysis carried out in the accomplishment of the proposed interactive English online teaching system. In order to prove the significance and effectiveness of the proposed interactive online English teaching system based on IoT technology, various experiments were performed that show the sublimity of the proposed system.

4.1. Design of the Experimental Environment. Indeed, an environment setting for the experimental work is an important and tough task in order to produce good results. All the experiments were performed on laptop systems having the specification of HP EliteBook840 Intel Core i7 7$^{\text{th}}$ generation and RAM of 16 GB, Windows 10 is the operating system used, and MATLAB has been used as a tool and programming language to carry out all the simulations. Multiple experiments have been performed to check the performance and efficiency of the proposed system. At first, a total of 10 students were selected randomly from the university students for the experimental work in order to carry out the regular English online teaching. After that, a total of 15 students were selected randomly from the university students for the experimental work in order to carry out the regular English online teaching. In order to avoid the uniformity of experimental results, the traditional mobile terminal interactive teaching system (system 1) based on augmented reality technology and the three-dimensional interactive teaching system (system 2) based on the contradiction space are used as comparison systems in order to show the sublimity of the system proposed in this study.

4.2. Results and Analysis

4.2.1. Time Test of Students' Acceptance of the English Teaching Content. The practical application effect of different systems can be seen from the time students receive English teaching content. The less time students spend on receiving the teaching content, the stronger the application effect of the teaching system is. With the assistance of the teaching system, students can quickly accept and comprehend the English knowledge they have learned.

In view of the same degree of difficulty of the teaching content, three different teaching systems were adopted to conduct online interactive teaching for 10 students, requiring students to fully master the content to be learned. After the implementation process, a comparison study is conducted to show the effectiveness of the proposed system. The comparison results are shown in Table 1.

By analyzing the experimental data shown in Table 1, it can be seen that due to different teaching methods adopted by the three teaching systems, the time for students to receive the teaching content varies greatly. After the application of the two utilized traditional teaching systems, the time for students to receive the teaching content is more than 14 min. However, after the application of the interactive English online teaching system based on the Internet of Things designed in this study, the time for students to receive the teaching content is significantly shortened, and the minimum time is only 10.02 min, and the maximum time taken is 12.45 min. Figure 7 shows a comparison of the time

Table 1: Comparison of the time of students (10 students) receiving the English teaching content.

Test subjects	Minimum time taken by students in accepting teaching contents		
	System 1	System 2	Proposed system
01	15.23	17.02	11.33
02	15.42	14.64	12.15
03	15.43	18.37	10.03
04	15.75	18.37	12.45
05	16.06	17.03	11.78
06	17.56	17.75	12.02
07	15.37	14.86	10.02
08	15.75	16.95	11.54
09	15.29	14.75	10.75
10	14.16	17.37	11.15

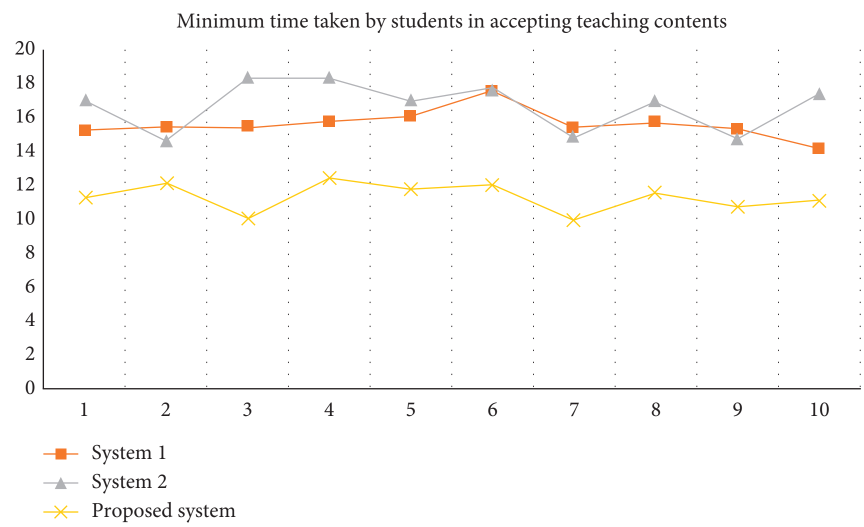

Figure 7: Comparison of the time of students (10 students) receiving English teaching contents.

taken by the students, i.e., 10 randomly selected students, in receiving the English teaching content.

Similarly, another experiment was conducted on 15 students selected randomly from university students using the three different teaching systems mentioned earlier. After the experiment, the three implemented teaching systems were analyzed, and a comparative study was conducted to show the importance of the proposed system over the two earlier approaches. Table 2 demonstrates a comparison of the simulation results attained via the tree teaching systems.

From Table 2, it is obvious that the time to receive the teaching contents varies using the three mentioned teaching systems. From the experimental results, it can be seen that the proposed system has an edge over the others in terms of time efficiency. The time to receive the teaching contents using the earlier two teaching system was more than 14 min, while the proposed system reduced the minimum access time to 10.02 min. Figure 8 shows a comparison of the time taken by the students, i.e., 15 randomly selected students, in receiving the English teaching contents.

4.2.2. Internal Consistency Reliability Test. Internal consistency reliability test refers to the measurement that whether the same results exist when the same teaching system is used to teach English to the same objects under the same conditions. In general, a consistency reliability of more than 75% is considered reliable, indicating that the teaching system can meet the teaching needs. The calculation formula of internal consistency reliability is as follows:

$$\kappa = \left[\frac{1-(X-Y)}{(X+Y)}\right] \times 100\%. \tag{7}$$

Among them, α and β represent the test records of different teaching observers, respectively, and the default is $\alpha > \beta$. The actual teaching process of different teaching modes was observed by different observers, and the observation results were recorded to calculate the consistency reliability among observers. The results of the internal consistency reliability test are shown in Figure 9.

In Figure 9, the internal consistency reliability of system 1 is 69%, and that of system 2 is 66%. The internal consistency reliability of the system proposed in this study is higher than the mentioned two systems, i.e., 96%. The internal consistency reliability of the proposed system exceeds the limit of 75% and far exceeds the internal consistency reliability value of the other two teaching systems. Therefore,

Table 2: Comparison of the time of students (15 students) receiving the English teaching content.

Test subjects	Minimum time taken by students in accepting teaching contents		
	System 1	System 2	Proposed system
01	14.20	17.02	11.33
02	15.34	14.64	12.15
03	15.73	18.37	10.03
04	16.01	18.37	12.45
05	15.40	17.03	11.78
06	16.61	17.75	12.02
07	14.70	14.86	10.02
08	15.72	16.95	11.54
09	16.06	14.75	10.75
10	15.10	17.37	11.15
11	16.22	15.55	10.12
12	14.76	17.23	11.22
13	15.36	16.20	10.80
14	16.12	16.90	10.77
15	15.45	17.20	12.60

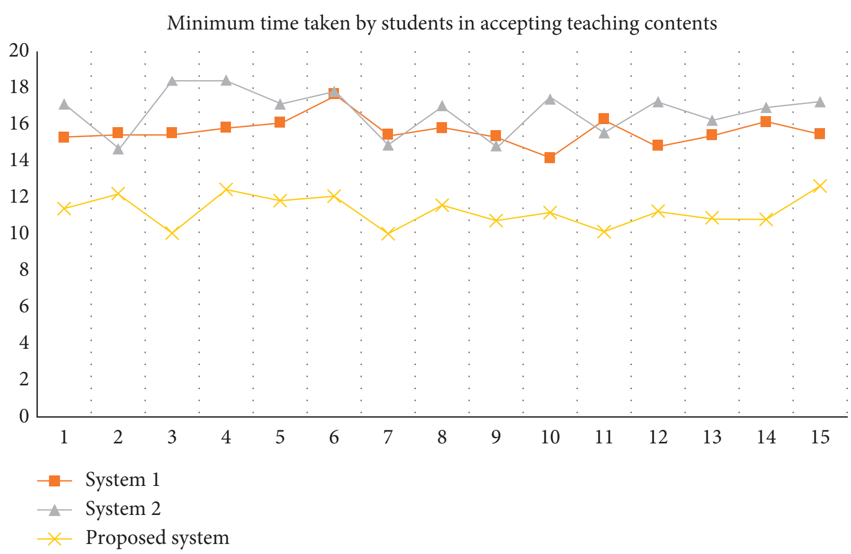

Figure 8: Comparison of the time of students (15 students) receiving English teaching contents.

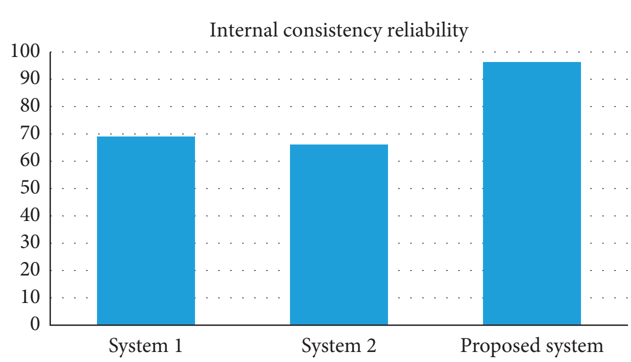

Figure 9: Comparison of the internal consistency reliability of different teaching systems.

it can be concluded that the application of the interactive online English teaching system based on the Internet of Things designed and used in this study can better guarantee the quality of online English teaching in the consistency reliability experiment verification.

4.2.3. Teaching Achievement Inspection. Teaching results can be reflected by the performance of English test scores of the students. The higher the test scores of students, the better the teaching results of the teaching system. Therefore, students' English test scores are used as indicators to verify the

Table 3: Comparison of teaching results of different teaching systems.

Test object number	Student English test score		
	Proposed system	System 1	System 2
01	97	84	89
02	93	95	87
03	93	88	86
04	94	92	82
05	95	91	87
06	96	87	85
07	94	85	85
08	92	85	82
09	95	93	90
10	96	86	87

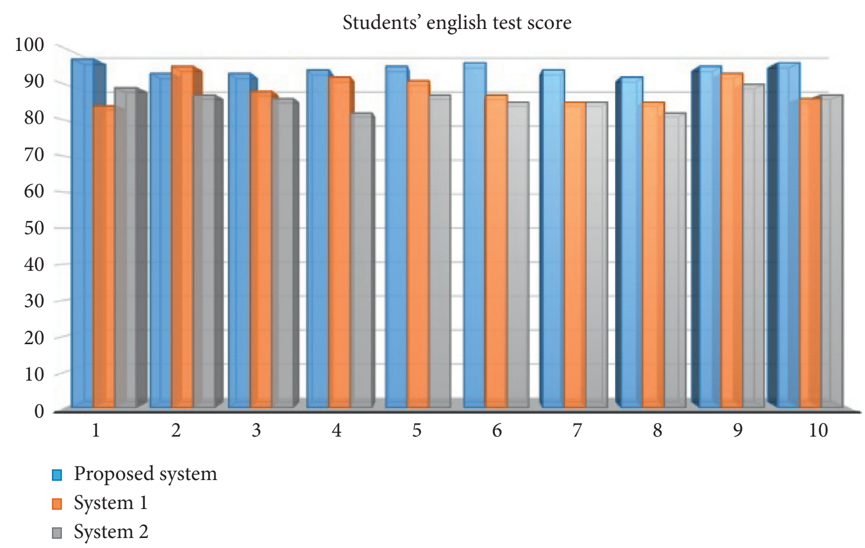

Figure 10: Comparison of teaching results of different teaching systems.

teaching results of different systems. The full score is set as 100 points, with 85 to 100 points as excellent, 60 to 84 points above as qualified, and 60 points below as failing. The results are shown in Table 3.

By analyzing the experimental results in Table 3, it is quite obvious to find out that the student's acceptance of the English teaching content varies with the adoption of different teaching systems. In the proposed system used in this paper, the average English score of all the students was above 90, and the highest test score observed was 97. Table 3 demonstrates that the English test scores of students using the proposed system are significantly higher than those of the other two traditional teaching systems. Figure 10 shows the English test scores of the randomly selected 10 students using the three teaching systems used in this study.

After the application of the interactive online English teaching system based on the Internet of Things technology designed in this study, the time for students to accept the teaching content is shorter, and the test scores of students are significantly higher than those of the other two traditional teaching systems. At the same time, its internal consistency reliability is as high as 96% which is far greater and significantly exceeding the normal threshold value, i.e., 75%. Therefore, the system used in this study has a better application effect and higher application value.

5. Conclusion

The demand for online teaching systems is increasing with the passage of time due to several reasons. Keeping the demand and significance of online teaching systems in consideration, in this study, an interactive English online teaching system is designed in the network Internet of Things environment. The experimental results show that, after the application of the online teaching system designed in this paper, the time for students to accept the teaching content is shorter, and the students' English test scores are significantly higher than those of the traditional teaching systems. At the same time, its internal consistency reliability is high, which fully demonstrates the effectiveness of this system and proves that it achieves the design expectation. Indeed, security is an important factor that increases/decreases the significance and importance of a system. To increase the security of the proposed system, there is a need for a security module which is the future work of this study.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Retraction

Retracted: Design of Ideological and Political Multimedia Network Teaching Resources Integration System Based on Wireless Network

Scientific Programming

Received 29 August 2023; Accepted 29 August 2023; Published 30 August 2023

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] L. Rong, "Design of Ideological and Political Multimedia Network Teaching Resources Integration System Based on Wireless Network," *Scientific Programming*, vol. 2021, Article ID 4293771, 15 pages, 2021.

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Research Article

Design of Ideological and Political Multimedia Network Teaching Resources Integration System Based on Wireless Network

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The main purpose of the integration of network media and middle school ideological and political course is to better realize the moral education function of middle school ideological and political development. The use of resource integration technology to manage distributed teaching resources is conducive to improving the level of information construction in colleges and universities, and so on. This paper puts forward the integration system of ideological and political multimedia network teaching resources based on wireless network. Firstly, it presents an overview of the Radio Resource Management (RRM) problem and projected strategies within wireless network framework, where several Radio Access Technologies (RATs) are collectively controlled and identify the different activities relating to the CRRM issues. Secondly, this paper targets providing a summary of the RRM problem and projected solutions within wireless network. Thirdly, the theoretical elements of the design and the teaching resource management assessment process are clarified by using XML as the data exchange carrier to realize the automatic integration of teaching resources. Fourthly, we have used dSPACE platform, by calling its API function, which then call the subscribe function of dSPACE framework and store the subscription information in the database. Whenever new teaching resources enter the subscribed field, the dSPACE framework will automatically send e-mail to the subscribers. Finally, during the operation of the system, all functions operate normally and have strong security, so as to avoid the illegal theft or leakage of the data about the education system.

1. Introduction

With the rapid growth of the number of networked colleges, the mode of distance teaching and learning is constantly changing, which makes the characteristics of digitalization, networking, and interaction of distance education more and more prominent. Nowadays, network teaching has become one of the most important teaching modes [1]. Due to the heterogeneity and tight coupling of development platforms and tools, a large number of educational resource systems cannot be interconnected. The resource sharing and software reuse and the phenomenon of "Information Island" still exists in colleges and universities [2]. With the development of information technology in colleges and universities, the types of educational information resources are complex and diverse and disordered, the quantity is increasing rapidly, and the quality is uneven. In fact, these resources are still in the low-level and low-efficiency repeated construction [3]. If we use the traditional way to integrate the existing education resource system, it will cause problems such as long cycle, large investment, and lack of unified standards, so it is difficult to fully ensure the orderly, intensive, and optimized resource integration services.

Practice teaching is a very important link in the teaching process of ideological and political theory course, which plays an important role in improving the effectiveness and acceptability of ideological and political education, but the current practice teaching effect in colleges and universities is not ideal [4]. Discussing the connotation, principles, structure, content, and evaluation system of the new practical teaching resource integration system for ideological and political theory courses will help break the theoretical research on the single and traditional practical teaching mode and open up the practical teaching system of ideological and political theory courses in theory. The new field of research enriches the content of the current theoretical research on practical teaching of ideological and political theory courses [5]. Heterogeneous network technology integrates wireless networks to achieve the purpose of seamless docking, providing users with good service content. Centralized Radio Resource Management (CRRM) starts to carry out correlation function algorithm according to the received data information and transforms it into a feedback strategy that Radio Resource Management (RRM) can adapt to and hands it to RRM to calculate the instruction of the teaching system. The RRM utilities are largely accountable for the spectrum allotment of multi-RAT, where procedures for interference investigation and mitigation are applied. The network teaching resource integration system adopts B/S (browser/server), adopts a multilayer application system structure, and the user interface is realized through a Web browser and uses XML technology to effectively integrate teaching resources. With the "Model–View–Controller" (MVC) model as the concept, the overall structure of the system is designed in the form of Struts, and XML is used as the data exchange carrier to realize the automatic integration of teaching resources.

This article aims to provide an overview of the RRM problem and projected strategies in a within 4G and 5G framework, where several Radio Access Technologies (RATs) must be collectively controlled and to abstractly identify the different activities relating to the CRRM issues. This paper further targets to provide a summary of the RRM problem and projected solutions within 4G and 5G framework, where several Radio Access Technologies (RATs) must be collectively managed, in order to establish a wireless network for the ideological and political multimedia network teaching resources integration system.

The rest of the paper comprises the following. In Section 2, we present an indication of related works. In Section 3, we deliberate our planned work. In Section 4, we discuss the experimental effort. Lastly, the conclusion of this research work is discussed in Section 5.

2. Related Work

Tight integration of new information technologies with modern education and teaching is not just a significant growth policy for Chinese education but also a global trend. The researchers of [6] investigated how to generate the best Golomb size series in an elastic Wavelength Division Multiplexing System using a modern parallel hybrid multiobjective bat algorithm. Furthermore, the researchers have described and compared the natural heuristic-based algorithm for seeking close optical sequences in WDM channel allocation in [7]. In [8], the author discovered that artificial neural networks can learn the potential laws among outputs and inputs evaluate and measure new data and estimate required output via the research and analysis of input and output data. The nature of AI is no more its theory, but rather human purposefulness, conceptual structure, meaning, and everyday intelligence. The study findings of human subjectivity are still missing in the production of artificial intelligence, and the work of integrating artificial intelligence production with ideological and political learning is also missing. Some experiments are biased and incomplete, focusing on only one aspect of artificial intelligence. Marshall McLuhan delivered a speech titled "The Digital Revolution: Modern Transformative Power of the Internet" at a national conference on higher education in March of the same year. As a result, the term "fresh start" is in the media spotlight for at minimum half a century, long before Marshall McLuhan's address. However, as the community has seen, the term "digital media" has grown in popularity in the United States, since the 1960s, and the concept has since been adopted worldwide [9]. Much advancement in future network development has been rendered since more than 10 years of basic research discovery and research development [10]. In system architecture, there are many significant paths: information-centered systems, promoting cellular services, fusion systems that integrate computation awareness and memory, and systems that separate control plane and data plane, among others. Projects like Netlnf [11], NDN, and DONA are part of the information-centric system (ICN). This project's aim is to depict the existing "location-centric" network [12]. It is capable of resolving existing network material, as well as repeated delivery as well as other problems. Transportation first [13] is the key representative of the mobility system. The infrastructure is currently focused on fixed end-to-end connections and is unable to meet the growing demands of mobile products and systems. A mobile scene-oriented core network [14] comes first. It could provide products such as vehicle connectivity and reliable mobile assistance. Computation, awareness, and memory incorporation can broadly incorporate view, computing, and memory into the system, allowing computing to lead transmitting, memory to assist propagation and breaking via the existing network's simple single data transfer feature. This study will address a gap in the existing study by combining the creation of an ideological and political multimedia network teaching tools implementation system that relies on a wireless network, with the goal of further realizing the moral education role of middle school ideological and political courses.

3. Proposed Work

It is important to build a complete ideological and political multimedia network teaching resources integration system to ensure the creative growth of the ideological and political multimedia network teaching resources integration system based on wireless network. The system's functions are split, and different roles are modeled using Extended Modeling Language (XML). The system functions are distributed into three separate roles based on the current investigation and study of multimedia network teaching tools integration system: network administrator, learners, and educators. It is all about the immediate conflict of views when teaching ideological and political courses. Learners are seen as involved people with their own opinions. Such data are collected, evaluated, and identified using data processing techniques and then through human-computer interaction, using the previous acquired data, focused instruction, and support. Multimedia teaching resource integration, user login process control, electronic document control of instructional materials, investigation, launch, and use of electronic repositories of teaching resources, and Data Storage Resource Repository are the functions of the proposed framework.

According to the inherent characteristics of the network, heterogeneous network technology integrates wireless networks to achieve the purpose of seamless docking, providing users with good service content [15]. If the network utilization rate is to reach a certain high value, several wireless networks are required to achieve unified management through some technologies. In the 3GPP specifications, RATs such as WCDMA, local area network, and GSM/EDGE all realize their coordinated management through CRRM [16]. In this process, each RAT has played a very important role. The main responsibility of the RAT is to perform call admission control. At the same time, it also needs to be responsible for scheduling, HHO, and local power control (Power Control), as shown in Figure 1. Figure 1 shows that the CRRM Entity consists of Initial Rate Access Algorithm and Virtual Handoff Algorithm, interacting with RRM entities in bidirectional mode, that is, RRM measurement and RRM decision-making. This process may further be explained in Figure 1.

The core function of Centralized Radio Resource Management is to control the primary communication, which can be switched to different networks at will, after reasonable resource allocation, to further improve network utilization and use scheduling techniques to solve network congestion [17]. CRRM starts to perform correlation function algorithm according to the received data information and transforms it into a feedback strategy that RRM can adapt to and hands it to RRM to calculate the order. In the process of forming response points, the server's response continuously transmitted to PEP and then converts to a collective algorithm for execution.

3.1. Ideological and Political Multimedia Network Teaching Resources Integration System. Network ideological and political education is to use modern information dissemination technology, on the basis of inheriting and developing traditional ideological and political education, guided by Marxism–Leninism, Mao Zedong Thought, and Deng Xiaoping Theory. Use the basic principles of Marxism–Leninism and scientific knowledge related to psychology, behavior, communication, modern information technology, and so on to cultivate the socialist "four-property" "newcomer's educational activities" [18].

3.1.1. Integration of Wireless Network and Ideological and Political Multimedia Network Teaching Resources System. Every information technology, like Electronic Teaching Methods, now needs a wireless network. As a consequence, its incorporation is a must in order to avoid hardware and technological design implementation problems, as well as taking full advantage of the large quantities of data produced by such a system and gain processing and analysis versatility. Finding helpful info from the Ideological and Political Multimedia Network Teaching Resource is a difficult task, particularly given the massive increase in data generated every week by online learning. To address this problem, wireless networks offer cutting-edge technology, approaches, and strategies that are both effective and simple to implement.

According to Figure 2, Cloud layer is the lowest point which is constructed with computing, storage, and network resources that are virtualized and distributed as resources via the WAN Link. The latter would be accountable for supplying virtual computing services required to provide e-learning applications with a suitable execution environment. In addition, the assets in this layer are scalable. This layer has the advantage of providing a scalable, robust, and fault-tolerant architecture. The Cloud layer, which involves decentralized storage systems and a Multimedia Streaming Server, is the 2nd layer of this strategy. Another is the e-learning layer, which contains information in the form of educational material, knowledge about the learner or teacher's record, course registrations, and so on. Such data are very valuable and will be effective in developing customized learning opportunities by adjusting learning material to the requirements of every learner in order to provide a better learning tool. The User Layer, which includes teachers, students, and administrators who want to access data from the Multimedia Streaming Server, is the final layer [19].

3.1.2. Integrated System Architecture. It is necessary to ensure that the system operates safely and stably in the network system of our hospital. The server side of this integrated system is the resource server in the security service area in Figure 3.

According to the overall construction goals and design principles of this system, the computer network teaching resource integration system based on the DSpace platform of our hospital adopts B/S (browser/server), which is browser and server structure design. Its architecture is shown in Figure 4.

The computer network teaching resource integration system based on the B/S mode adopts a multilayer application system structure and the user interface is realized through a Web browser [20]. Its overall structure is shown in Figure 5.

The core step of the automatic integration system of teaching resources is to create a cross-platform electronic archive with high portability and openness. A sign of the maturity of an automatic integration system of teaching resources not only includes the ability to automatically integrate information in electronic archives but also includes the electronic processing of required paper documents [21]. The system uses XML technology to effectively integrate teaching resources and encapsulates low-level APIs by programming the development environment to the object to complete the establishment of a practical object module with independent functions. The reason why XML can complete data exchange between different platforms is that it itself is a

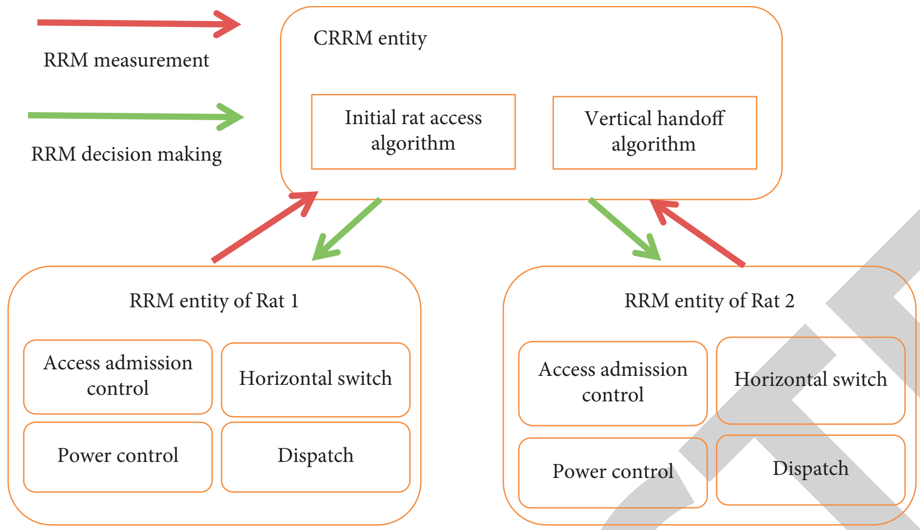

FIGURE 1: Radio resource management.

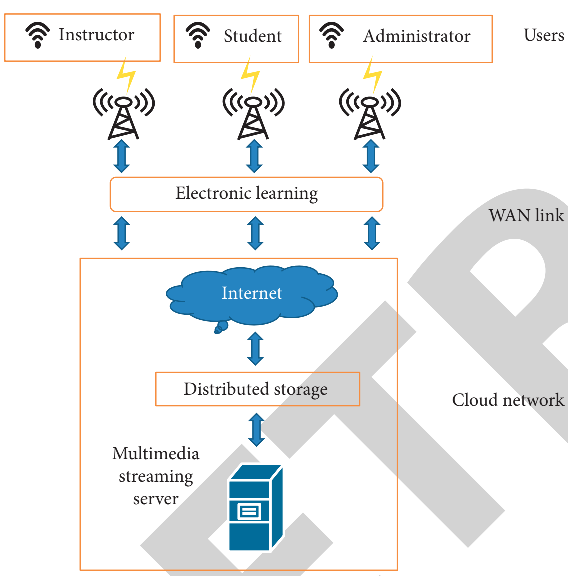

FIGURE 2: Integration of wireless network.

file format that exists in text form. The XML format file is composed of many parts that are described as elements, and tags are usually used to describe the elements. Therefore, the markup method is used to describe the XML file, and on the basis of ensuring the original data semantics and structure are unchanged, the Internet data exchange is carried out, and the flexible and lossless data exchange between different systems is guaranteed [22].

3.1.3. Student Module. In addition to being an intelligent system, the pupil module is also an intelligent system. Its knowledge base holds a variety of student learning habits. The student module's aim is to create a student model by determining the current learning development of individuals using various diagnostic methods. The entire data collection would be free of personal motivation and sentiment, guaranteeing the data's accuracy and reliability. The pupil module primarily accomplishes two things. The first is to recognize students' errors, that is, to determine what kind of confusion or knowledge students lack in order to generate the currently incorrect response. The issue of "who is studying" is central to the design of the pupil's information condition. The pupil model explains how well students comprehend and control the material being taught. According to the particular conditions of the student model, ITS may adapt the teaching strategy as well as provide adequate feedback. The other is student conduct definition, which describes how students make mistakes.

3.1.4. Teaching Module. It is important to apply artificial intelligence principles in terms of information structure, reasoning processes, and natural language comprehension to resolve the limitations of conventional Computer-Aided Instruction (CAI). As a result, a number of experts have suggested smart teaching systems, as seen in Figure 6.

According to Figure 6, each topic has only single teacher user, who is able to build the question bank, examining examination papers and evaluating examination papers, and is referred to as the library construction teacher. However, in order to collaborate with the higher performance of teaching work, it is also important, in the current situation, to enable nonteaching teachers to temporarily gain access to topic question bank data in order to assist the teachers who are building the database in completing their work.

3.2. Multimedia Teaching Resource Integration System. Because MVC is only a design concept, not an application technology, the technical solutions designed by different designers in different fields based on the MVC concept are extremely different. Here, full consideration is given to the characteristics of the automatic integration of teaching resources, the confidentiality of relevant information involved in the integration process of teaching resources, and the universality of users of the integration of teaching resources. With the "Model–View–Controller" (MVC) model as the

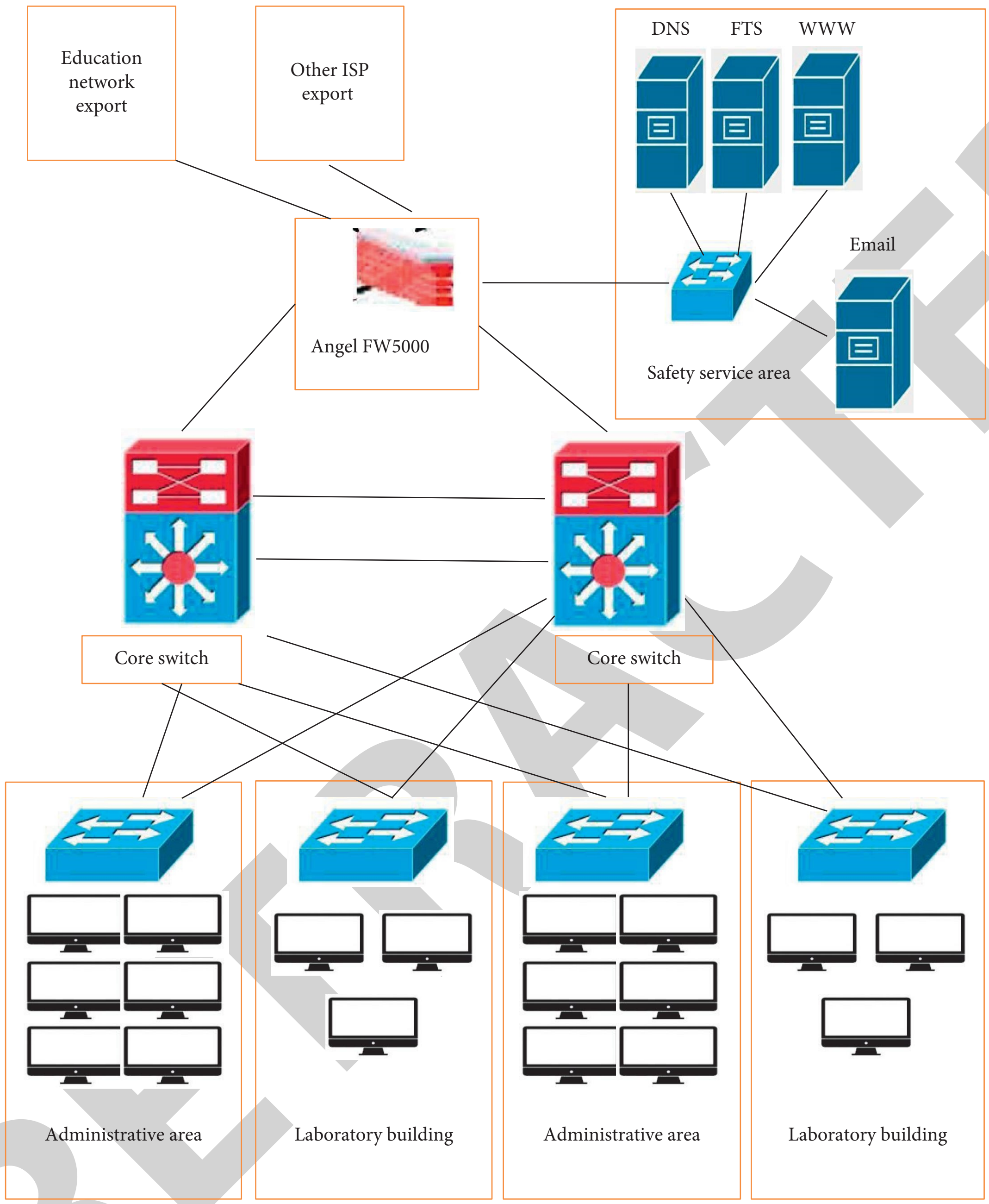

FIGURE 3: Network architecture system.

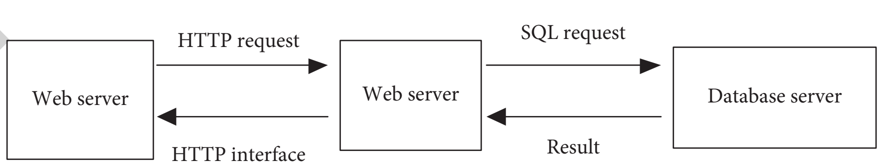

FIGURE 4: B/S architecture.

concept, the overall structure of the system is designed in the form of Struts structure, and XML is used as the data exchange carrier to realize the automatic integration of teaching resources. The result is shown in Figure 7.

The Struts system well interprets the concept of the MVC pattern, mapping models (Model), views (View), and controllers (Controller) to components in Web applications and integrates teaching resources into a unified framework. It

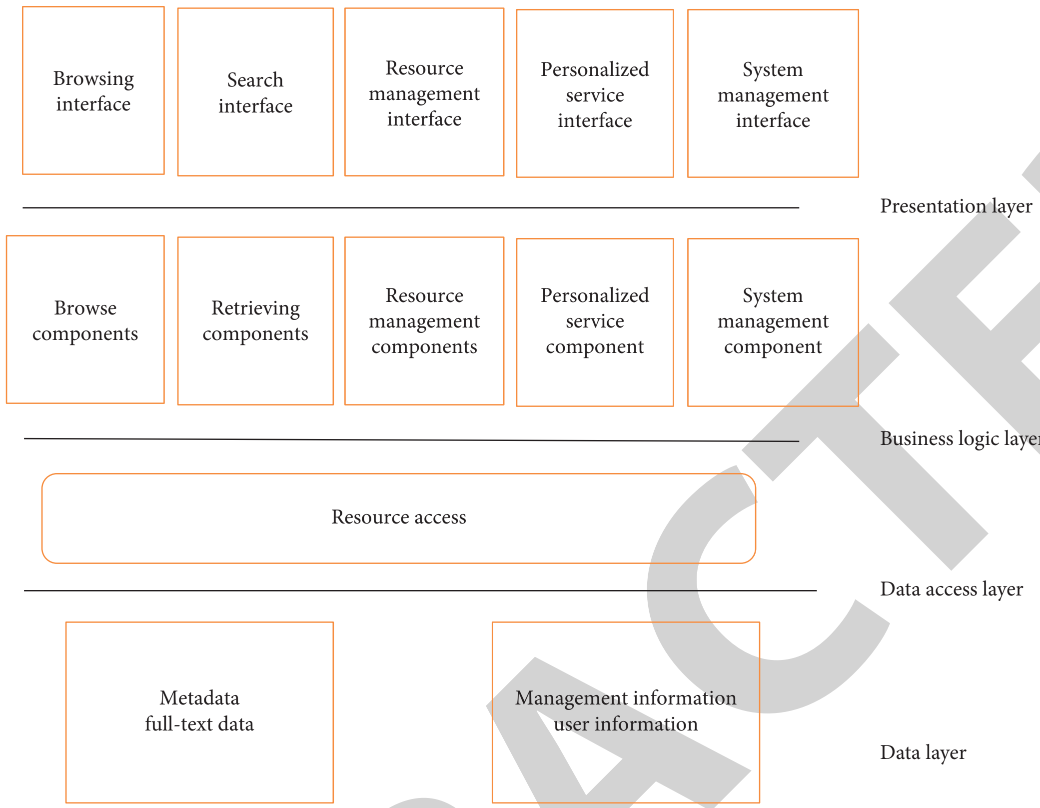

Figure 5: Overall structure.

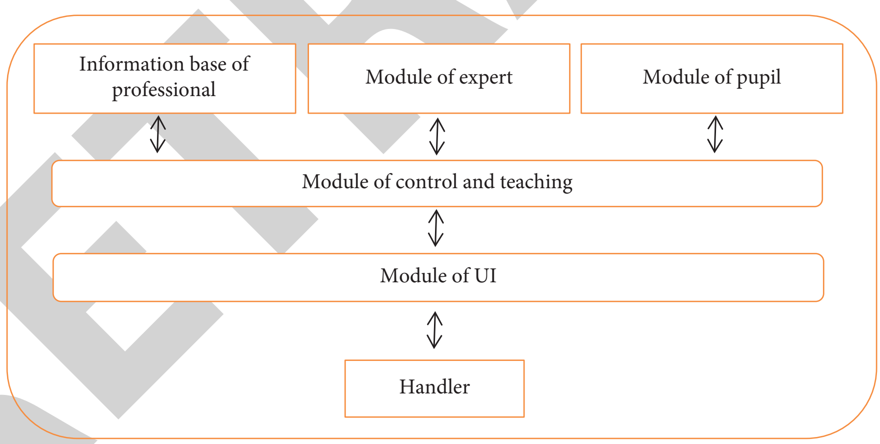

Figure 6: Teaching module.

provides a highly configurable MVC development model for Web development.

Based on the MVC hierarchical design concept, the system design adopting the MVC mode has the following advantages. (1) The separation of model, view, and controller allows a model to be displayed through multiple views. Expanding the control, other views can synchronously reflect the result of this control and realize the synchronous change of data. (2) The model has portability. Because the view of the model is relatively independent, if you want to port the model to a new platform, you only need to modify the view controller on the new platform. Therefore, the system's display and behavior separation design based on the MVC model not only simplifies the system functions and reduces the difficulty of operation and the later maintenance cost of the system but also effectively isolates the storage resources of the electronic archives, enhances the security of system background data, and further promotes the automatic integration of system information resources [23].

3.2.1. User Login Control Management. Establishing user login for the ideological learning platform has the aim of considering the ideological platform's protection and

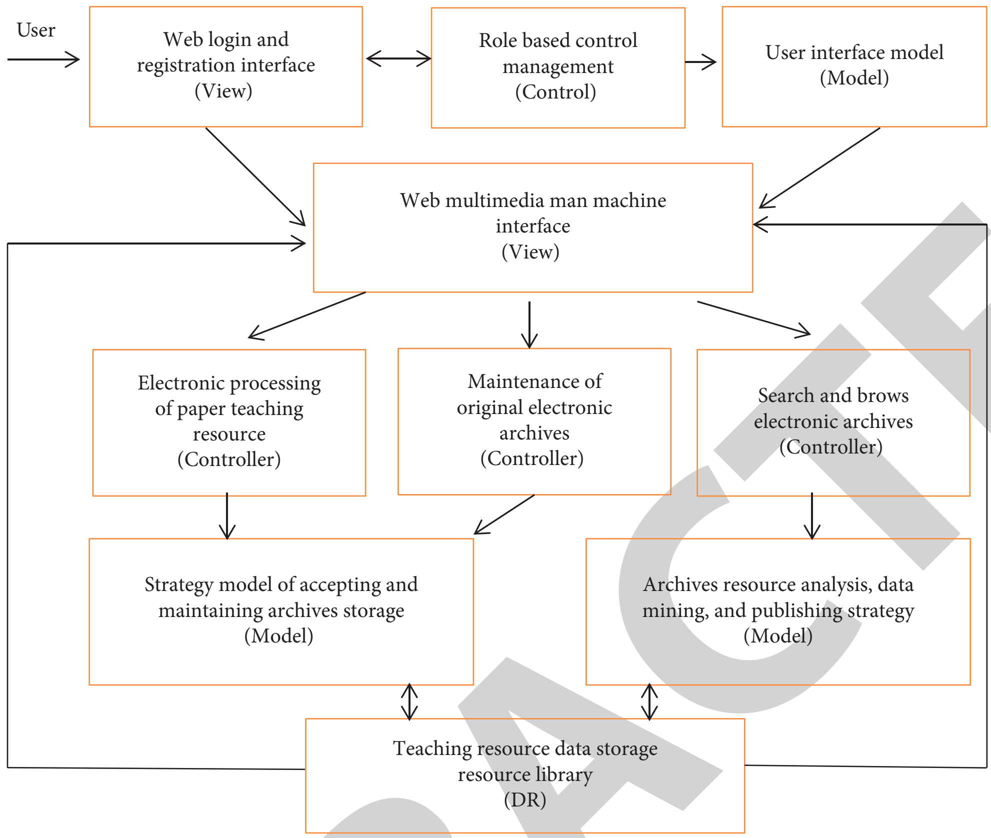

Figure 7: The functional structure design of the automatic integration system of teaching resources based on the MVC model.

adopting the user login process, which is also a statistical and monitoring tool for the academy's ideological students, so it is best to know via the framework. The amount of people using the digital learning platform and the level of attention are both indicators of growth. The supplementary platform's activity is an open platform focused on the campus network's activity. As a result, relevant service frameworks for secure system operation, such as authentication system, gateway, and data integrity security, are needed to ensure the system's and campus network's security.

The system uses role control management to realize the distribution of role work authority, which is an important measure that reflects the humanization and rationalization of system design [24]. When users log in to the system or register on the Web interface (View), they need to be approved by the role management controller and generate the corresponding user interface (View) according to different users and enter the multimedia human-computer interaction interface (View) through the corresponding model (Model). In the actual application of the system, the user can only see the page display in the foreground and cannot understand the completion of the relevant functions of the background database. Therefore, when providing data to the user, the user needs to provide the user with relevant roles and permissions. The administrator sets the corresponding roles and related permissions according to the user profile information, and incorporates the setting results into the database. After the user authority is clearly completed, the user can use the unique username and password to log in to the system and system applications within the scope of his authority. The operation flow chart of permission setting is shown in Figure 8.

3.2.2. Teaching Resource Electronic File Management. The management of electronic archives of teaching resources mainly includes the backup and restoration of teaching resources, among which the main objects of the backup and restoration of teaching resources are the file tables and file tables of electronic archives. Taking the backup of teaching resources as an example, the activity diagram is shown in Figure 9. According to the figure, the proposed Teaching Resource Electronic File Management is working in the following five stages:

Stage 1: during this stage, the user (Education System Administrator) provides his/her predefined ID

Stage 2: if this is valid ID then, this user can be able to log into the education system by submitting educational resource information backup request

Stage 3: in this stage, the interface of Web multimedia main machine swift to backup information of Education System Administrator

Stage 4: during this stage, the desired Education System Administrator enter backup information into the data backup of educational resources which then store in the database

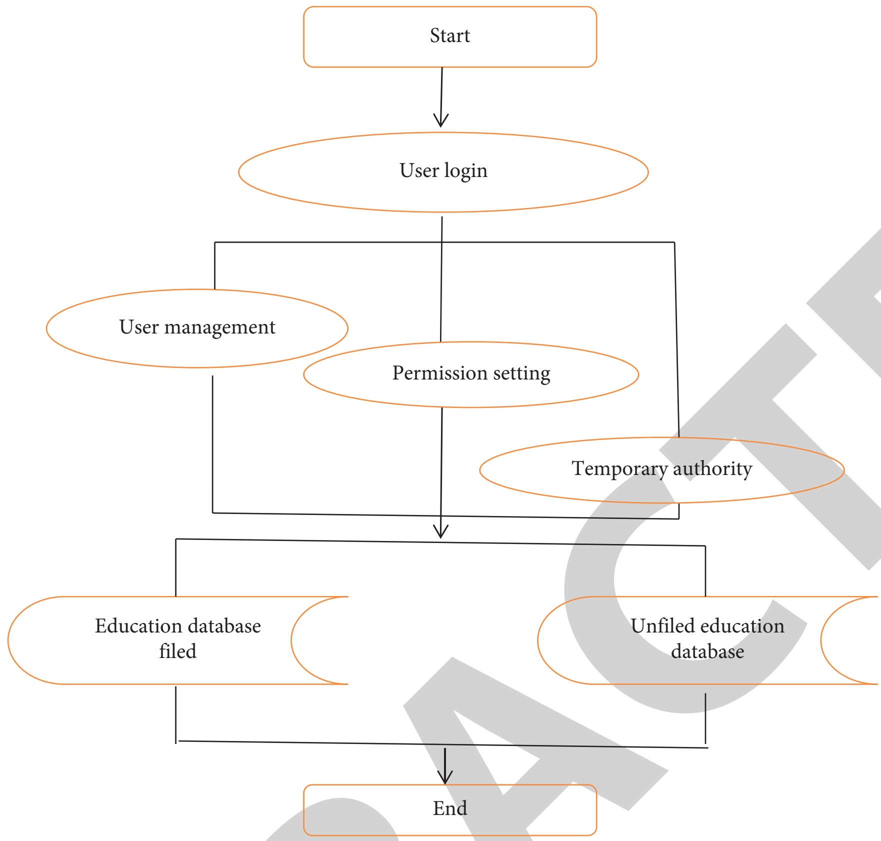

Figure 8: Operation flow chart of permission setting.

Stage 5: this is the final stage, during which the Education System Administrator displays success information from the database

In the process of teaching resource backup, firstly, the system administrator logs in to the system, sends data backup request to the Web multimedia human-computer interaction interface (view), receives the system prompt, inputs the teaching resource to be backed up, and after clicking the teaching resource backup, submits it to the database, completes the verification, and provides the feedback information to the system administrator.

3.2.3. Inquiry, Release, and Utilization of Electronic Archives of Teaching Resources. After the teacher user's request to query the electronic archives is sent out through the Web multimedia human-computer interaction interface (view), the best action execution method is sought through the archives resource analysis, data mining, and release strategy model, and the user's query interface (view) is returned through the graph, statistical report or target transformation data form. We archive resource analysis, data mining, and release strategy model (Model) after receiving the request from the controller; it will send the request to the database server and process the received information through specific strategies and methods. Data mining can be carried out if necessary. After all the above steps are completed, we release the teaching resources to the user view (View) that serves as the interface between the system and the teaching resources. The digital archive information provided to users by the digital archive resource library is realized by the electronic archive query and browse (controller) through the strategy model (model); the purpose is to facilitate users to query the required information in the huge digital archive information [25].

Systematic teaching resource services should not be limited to simply providing original teaching resources but should realize the synthesis, analysis, and processing of original teaching resources, and realize automatic integration of information based on knowledge element processing and secondary or even tertiary information transformation. At the same time, according to the openness of electronic archives and the degree of information confidentiality, effective methods are adopted to filter, encrypt, transform, process, and integrate information to promote the maximization of teaching resource intelligence and knowledge. To achieve the highest level of automatic integration of teaching resources system services.

3.3. Data Storage Resource Library. In order to ensure that the system can perform effective data management and efficient storage in a specific application environment and cater to the actual needs of users; it is necessary to build a database and application system with a reasonable and effective physical structure and logical mode. The data storage resource library is to realize the automatic information of the system. The ultimate goal of integration is to design a data

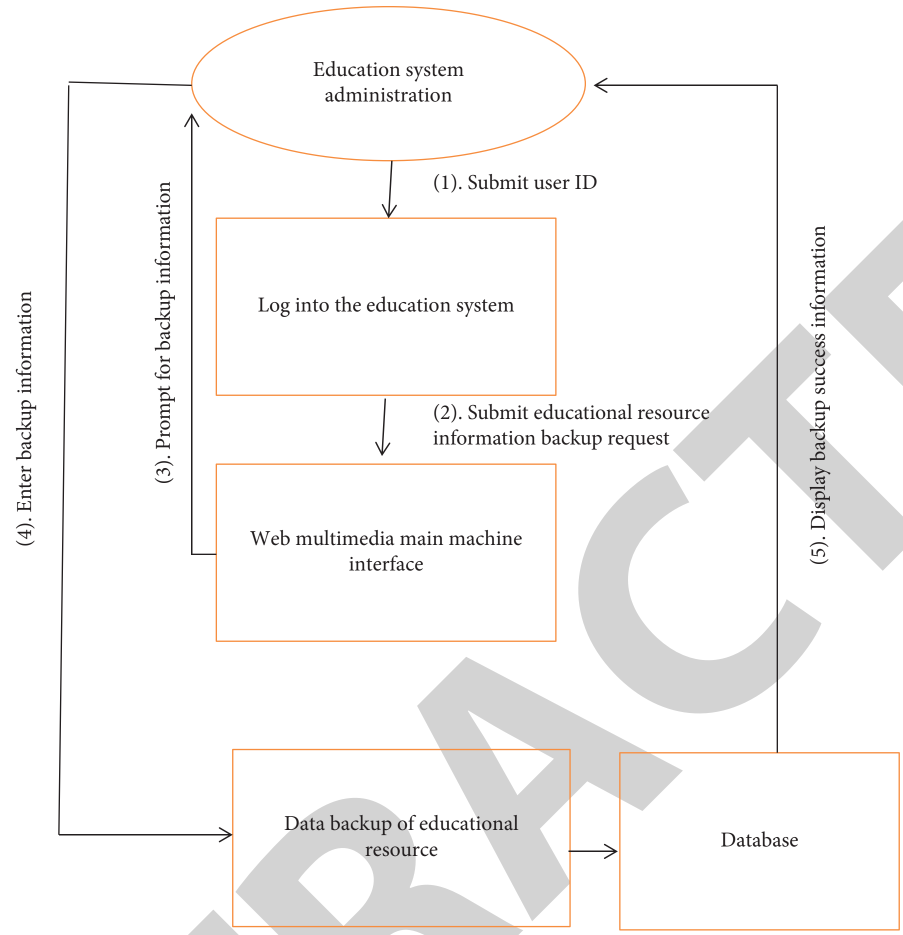

Figure 9: Teaching resource backup activity diagram.

storage resource library based on data requirements, physical structure, and logical mode. Relying on the Web computing method, using a convenient browser, without installing relevant software on the client side, the overall simple and fast operation of the system can be realized. The system data storage resource database includes photos, documents, and electronic archive data. The recorded electronic archive data mainly includes the electronic archive borrowing table, and return table. The specific composition information in the electronic archive borrowing table and return table is shown in Table 1.

The integration and download of teaching resources is the main design purpose of the teaching resources integration system. In the design of the function module, the powerful and perfect retrieval ability provided by dSPACE framework is fully utilized, and the browsing mode based on different standards is provided for the users of resources. Meanwhile, based on the technology of full-text retrieval and multicondition combination integration, the resource objects that can better meet the user's needs are located more quickly and accurately. The flow chart of the browsing and integration function of teaching resources is shown in Figure 10.

dSPACE is a free software platform that enables us to collect, save, index, maintain, and spread digital content such as text, video, audio, and information. dSPACE gives us a way to keep track of our resources and articles in a professionally managed archive, increasing their exposure and availability across period.

With the following three functions, dSPACE offers access to research output, scholarly articles, and online libraries:

(i) Encouraging the collection and consume of items, as well as metadata about the components

(ii) Facilitating quick access to the materials, through both identifying and finding

(iii) Encouraging the materials' long-term protection

The design of browsing and integration function is mainly based on the application programming interface provided by dSPACE, and the secondary development and encapsulation are carried out according to the needs of users. For the browsing function, after the user specifies the browsing range and object, the API function of dSPACE is called, and the related parameters are input to get the result

Table 1: Educational resources electronic archives borrowing/returning table.

Field	Number	Name	Full name	Mechanism	Manager	Date
Type	Char	Char	Char	Char	Char	Date time
Length	5	55	15	15	25	10
NULL	No	No	No	No	No	No
Remarks	Primary key	No	No	No	No	No

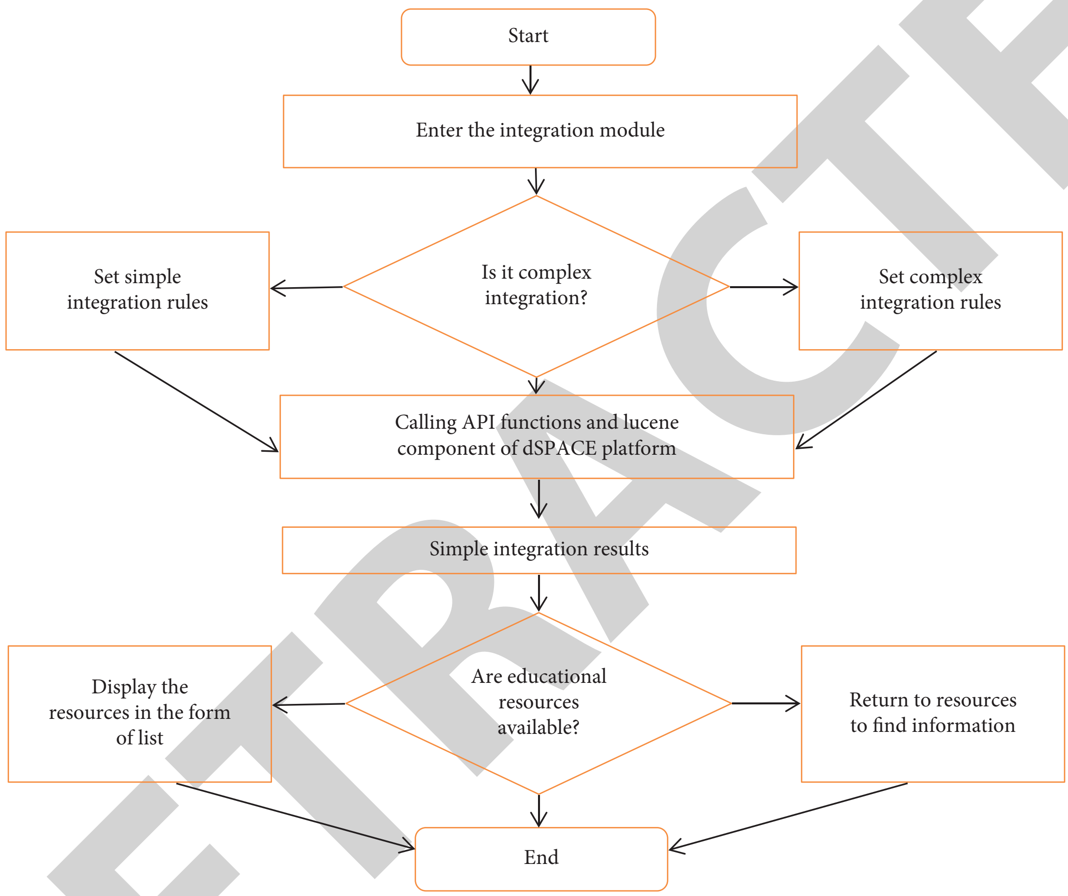

Figure 10: Flow chart of teaching resource integration function design.

information returned by dSPACE framework in the form of list, which is displayed in the user interface. For the integration operation, a combined integration mode based on multiple conditions is constructed. In the specific implementation process of the integration operation, the API function of dSPACE framework is mainly called, and Lucene full-text retrieval function of the framework is used.

In addition, in terms of the use of personalized resources, the subscription function of resources is designed based on dSPACE architecture. Every user of the integrated system can subscribe to the resources in a certain field in his working platform. The system function module will call the subscribe function of dSPACE framework and store the subscription information in the database. Whenever new teaching resources enter the subscribed field, the dSPACE framework will automatically send an e-mail to the subscribers.

4. Experimental Study

4.1. Experimental Environment. The development environment of this system is based on the dSPACE framework, the Eclipse integrated development environment is installed, and the Java language is the main development language. By calling the API functions of the dSPACE framework, the functional indicators to be completed in the system requirement analysis are realized. In order to ensure the normal operation of the system, JDK components, Tomcat components, and so on need to be installed in the development environment and configured according to the actual situation. In the choice of database management system, the Postgre SQL database management system is used, which is fully compatible with the dSPACE platform.

In the construction of the hardware development environment, Lenovo's Think Centre server is used as the application server and database server of the integrated system, and Huawei's products are used to build the network environment. The experimental tool is Load Runner, which can perform functions and simulate concurrent operations. The experimental operating system is Windows 7, the configuration tool is above IIS6.0, and the CPU is above Intel P4.

4.2. Experimental Program. Conventional testing methods include performance testing, load testing, stress testing, configuration testing, concurrency testing, reliability testing, failure recovery testing, and other test items. In the testing phase of the system, in addition to the regular functional tests, it is also necessary to conduct concurrent performance tests, which are triggered by multitask parallelism, such as uploading and downloading of questions, between teachers and students in a wireless network environment during the course of the class. To this end, testers have formulated concurrent performance testing strategies based on test requirements, set up corresponding test environments, and developed corresponding test cases.

4.3. Test Tools. In addition to the unit testing tool (NUnit) in the development process, some third-party tools, such as JMeter and Mercury LoadRunner, are required for performance testing during the development phase. Especially for session isolation under high concurrency conditions, XML data types involving I/O operations, and concurrent access optimization of exercise questions, we used JMeter as a testing tool to conduct corresponding tests.

4.4. Analysis of Results. For the student growth space experiment, the experimental example is shown in Table 2.

For the file management experiment, the experimental use example is shown in Table 3

For the file display experiment, the experimental use example is shown in Table 4

For the multivariate evaluation experiments, experimental examples are shown in Table 5

For the safety experiment, the experimental example is shown in Table 6

Analyzing the above experimental results, it can be seen that various functions of the education information integration management system based on the wireless network operate normally and have strong security. In order to display the information in the process of student growth from all aspects, the student information is provided comprehensively from multiple angles and levels, and the security of the system during the operation of the system is controlled in terms of physical security, network security, and data security. Among them, the components of the physical security module are hardware devices that support the maintenance of the normal operation of big data, such as communication circuit equipment and power supplies, which provide energy support for the normal operation of the system. The network security module mainly protects the software and hardware of the system in operation, thereby improving data security, avoiding threats to data security due to external natural and human factors, and maintaining the continuity of system services. The main function of the data security module is to protect the integrity and security of information data transmission and storage and to prevent the education system information data from being illegally stolen or leaked.

The simulation results and expert evaluation results are shown in Figure 11. It can be seen from the results in Figure 11 that the simulation results are close to the evaluation results given by experts. In Figure 11, not only the training but also the error rate is kept below 1.5%. Therefore, the ideological and political multimedia network teaching resources integration system (IPNTRS) based on wireless network is a reasonable.

FTP files have been used to transmit 1 kB to 150 kB files for the purpose to capture real-time throughput data in the network in the very same simulation model. Figure 12 depicts the research findings for comparing the proposed IPNTRS with TCPW, CUBIC, and EBE. As a result, the throughput achieved was not pointedly different from the predicted value.

Figure 13 shows a detailed analysis of congestion connection utilization using the IPNTRS (ideological and political multimedia network teaching tools integration system), EBE, CUBIC, and TCPW protocols. TCPW was unable to efficiently use the expanded congestion bandwidth, and compression was extremely slow, owing to the data stream to be sent simultaneously. CUBIC was unable to absorb the expanded bandwidth in a timely manner and therefore converged steadily. It should be remembered, however, that although CUBIC's weak results as bandwidth climbed, its usage was still comparable to TCPW by using effective bandwidth identification. When connection bandwidth models were present, EBE was able to react quickly and attain approximately almost double usage during the simulation phase, suggesting that it outperformed CUBIC, unlike TCPW, CUBIC, and EBE, substantially increased congestion connection usage, but it was still smaller than IPNTRS. In conclusion, even though the wireless network's bandwidth is unreliable, the IPNTRS would still display high congestion connection usage.

Table 2: Experimental use cases of student growth space.

Test plan	Specific description
Functional module	Student growth space module
Test function points	Verify the correctness of the student space
Operating system	Windows 7
Testing purposes	Verification of student space browsing and editing functions
Testing process	(1) After the user logs in, enter the student space (2) Click into personal space (3) modify the personal space style, log, etc. (4) Click the save button
Result	Ability to modify personal space style and logs

Table 3: Example of file management experiment.

Test plan	Specific description
Functional module	File management
Test function points	Add file
Operating system	Windows 7
Testing purposes	Verify the correctness of the add file function
Testing process	(1) After the user logs in, enter the file management (2) Click Add File (3) Enter the file after the interface pops up (4) Click the save button
Result	Success

Table 4: File display experimental use cases.

Test plan	Specific description
Functional module	Archive display
Test function points	User profile management
Operating system	Windows 7
Testing purposes	Testing the archive display module
Testing process	(1) After the user logs in, enter the file management (2) Click on the student's profile (3) Click the save button
Result	Display student files normally

Table 5: Examples of multievaluation experiments.

Test plan	Specific description
Functional module	Multiple evaluation
Operating system	Windows 7
Testing purposes	Verify the function of the multiple evaluation module
Testing process	(1) The user logs in to the system and browses the student's profile (2) Evaluate student files (3) Click the Publish button
Result	Multiple evaluations were successfully published

Table 6: Safety test cases.

Test plan	Specific description
Functional module	Safety test
Operating system	Windows 7
Testing purposes	Verify system security
Testing process	(1) User registration (2) Fill in illegal characters in basic personal information (3) Query personal basic information after clicking save
Result	Invalid characters entered are not executed

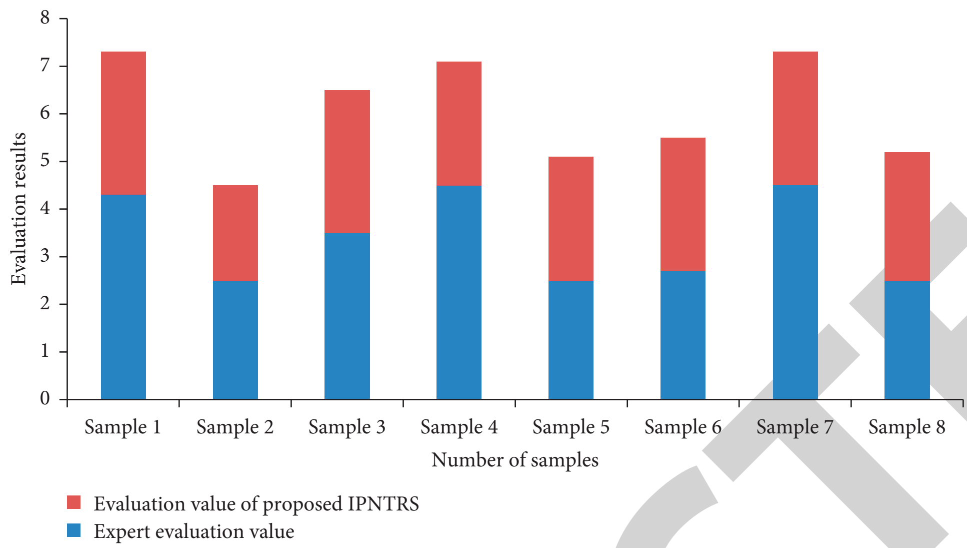

Figure 11: Comparison of evaluation results.

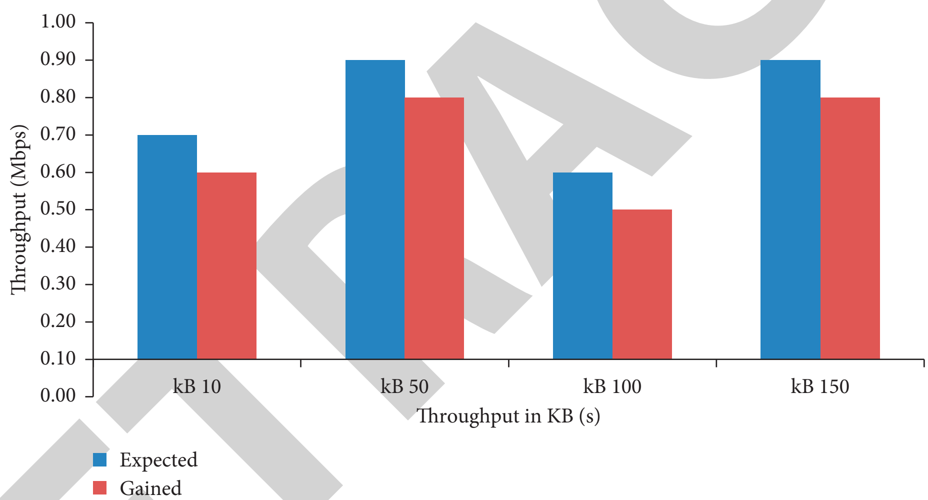

Figure 12: Comparison of throughput.

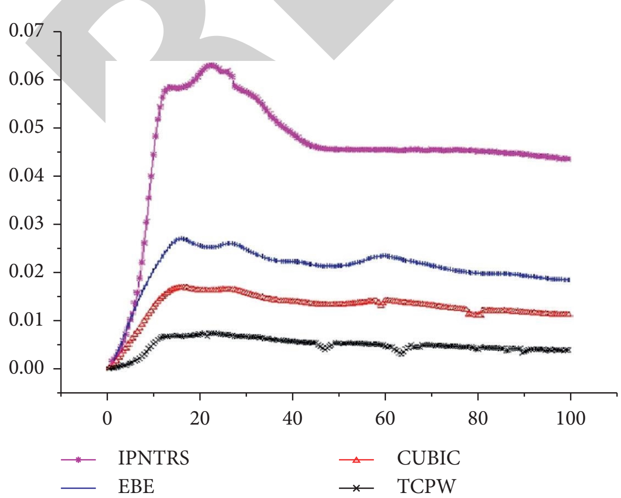

Figure 13: Comparison of utilization.

5. Conclusion

In this study, a wireless network-based ideological and political multimedia network teaching resources incorporation framework is proposed. The theoretical elements of the design and the teaching resource management assessment process are clarified. The structural design for the ideological and political multimedia network teaching tools integration framework based on wireless network in the big data setting is tested, driven by the model and mixed with current technologies. In addition, due to the lack of a unified management platform, valuable resources cannot be used effectively, which has a greater impact on the improvement of teaching efficiency. The use of resource integration technology to manage distributed teaching resources is conducive to improving the level of information construction in colleges and universities. The main purpose of the integration of network media and middle school ideological and political course is to better realize the moral education function of middle school ideological and political course. Network media has gathered rich teaching resources of middle school ideological and political course, which helps political teachers coordinate the relationship between various elements in the teaching process, create a free and independent learning environment, meet the personalized needs of students, and make the whole teaching system run orderly and freely. The dSPACE framework has solved a lot of problems, but there are still many problems in human-computer interface interaction experience, resource management efficiency, resource sharing, and so on. The next research directions include the following. One direction is to further improve and perfect the organization mode of teaching resources and metadata structure, so that the system can better adapt to the query needs of Chinese resources and provide better user experience. The second is to focus on strengthening the research and support of the user's personalized demand function, using data mining and other intelligent processing algorithms, in addition to the subscription function provided by dSPACE framework, but also to provide intelligent teaching resource recommendation function for users.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The author declares that he has no conflicts of interest.

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